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A DEMONSTRATION OF AREAWIDE WATER RESOURCES PLANNING - USERS MANUAL

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The Users Manual describes the function and operation of each component model, alternative models that could have been used, and elements of post computational analyses described. The Users Manual is intended to be used in conjunction with other references which are cited.

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FOREWORD

This report documents a demonstration of areawide water resources planning by the Metropolitan Washington, D.C. Council of Governments (MWCOG). The study was initiated prior to the current 208 program, and although the purposes and approaches are similar to a typical 208 project, the results should not be viewed as a prototype for the water quality analytical methods, evaluative procedures, scope and level of detail expected by the U.S. Environmental Protection Agency (EPA) in certifiable 208 plan reports. Certain agencies many find that some or all of the techniques described are applicable to their local situation, but many others will have neither staff nor data, time and financial resources to utilize the spectrum of tools described.

Publication by EPA does not indorse MWCOG techniques, nor does it imply that utilization of these detailed techniques are requisite to preparation of an adequate 208 plan. EPA has, for instance, recently published an Areawide Assessment Procedures Manual (EPA Report 600/9-76-014, July 1976) which describes a much simpler set of techniques which may be more relevant in areas where the systems are neither so large nor complex as those in Washington, D.C.

ABSTRACT

The Metropolitan Washington Council of Governments Framework Water Resources Planning Model is a comprehensive analytical tool for use in areawide water resources management planning. The physical simulation portion was formed by linking component computer models which test alternative future community development patterns by small area, estimate water demands by usage categories, calculate sewage flows based on water demands and add infiltration/inflow, simulate stormwater runoff, test application of alternative waste treatment management systems, and simulate the quality response of the region's major water body.

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INTRODUCTION

This Handbook documents the models used within the Framework Model chain. Of the thirteen models used within the chain, four are readily available to others. The EMPIRIC model used in projecting community growth patterns, the MAIN II water demand model, the Stormwater Management Model, and the Potomac Estuary Model are all generally available. The other models which connect these have been written by the staff of the Metropolitan Washington Council of Government. The description of the models used in the planning process is contained in Part A of this report, and in "Framework Water Resources Planning Model - Technical Summary", previously published by the Council of Governments. Reference to those documents in conjunction with this Handbook is essential.

This chain of models was developed over a number of years to facilitate water resources planning in the Washington Metropolitan area. It has played a major role in both water supply and waste treatment planning prior to the inauguration of Areawide Waste Treatment Management Planning under 208.

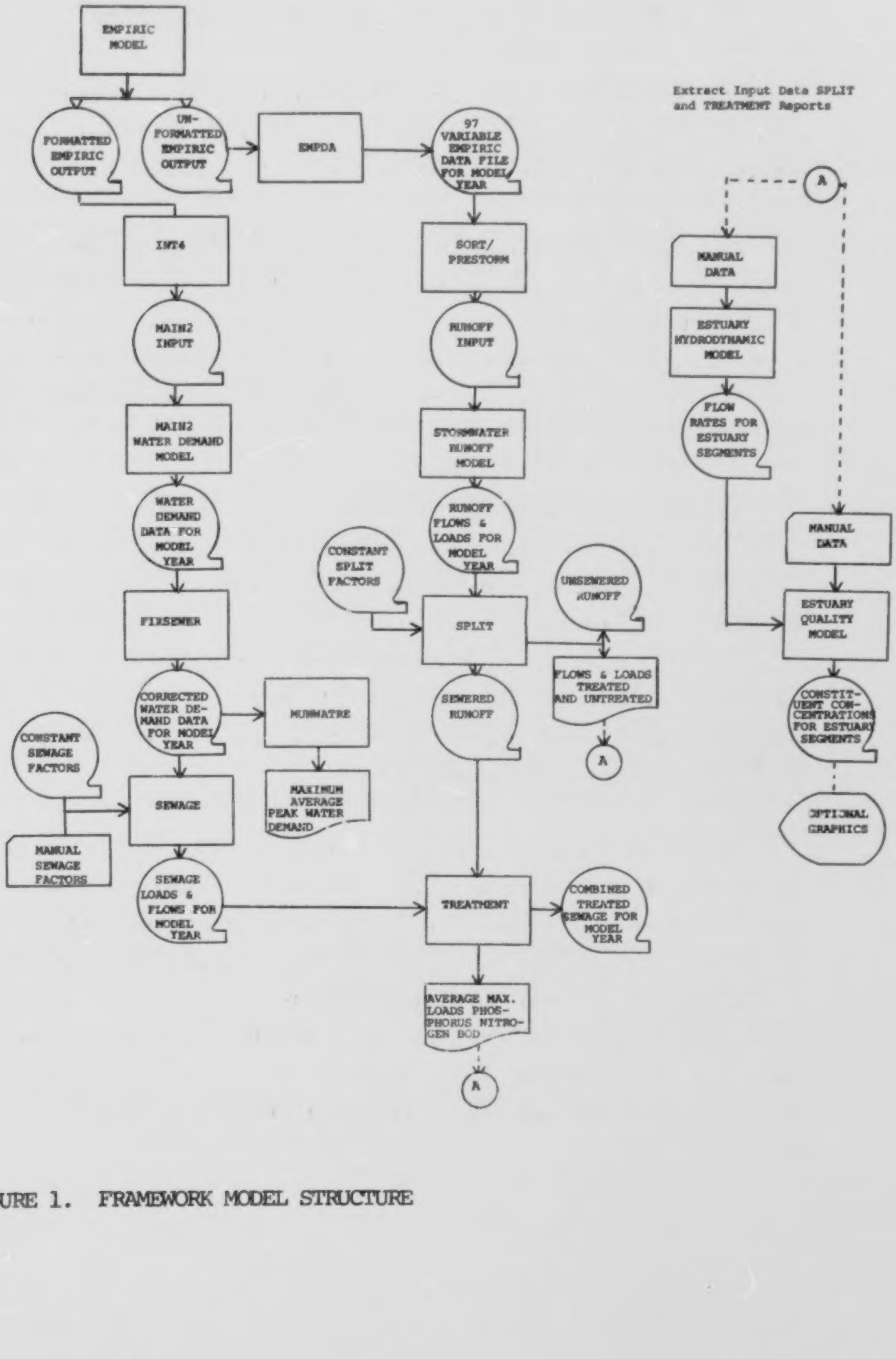
DESCRIPTION OF THE FRAMEWORK MODEL CHAIN

The Framework Water Resources Planning Model (Framework Model) is a planning tool for estimating and evaluating the effect of alternative public policies on the major components of the urban water resources system.

Exercised as a complete unit, the Framework Model can simulate the quality response of the area's major water body to alternative future land use development policies, different wastewater treatment processes and points of discharge and the quality response of the Potomac Estuary. The Framework Model is actually a series of linked models that are illustrated in Figure 1.

The Framework Model can be used to simulate the Estuary response to facilities or activities which divert, augment, or contaminate the Potomac River before it enters the region or flows into the Estuary. The construction of power plants and water supply intakes will reduce river flow while the construction of reservoirs could increase normal river flows. Uncontrolled agricultural activity or the expansion of urban development with its attendant runoff could degrade river water quality and decrease the allowable waste discharges within the region.

The above discussion highlights how the Framework Model can be exercised in different ways to satisfy urban water resource planning needs. The simulations of the water resource system with the Framework Model started with the output of the Community Development Component. While several runs with different planning assumptions were made, the model run number 6.2, modified by local government planning agencies, was selected for a variety of planning functions within the region. Alternative 6.2 Modified formed the basis for the Framework Model runs described in this report.


Extract Input Data SPLIT and TREATMENT Reports

EMPIRIC MODEL
FORMATTED EMPIRIC OUTPUT
UN-FORMATTED EMPIRIC OUTPUT
EMPDA
97 VARIABLE EMPIRIC DATA FILE FOR MODEL YEAR
INT4
SORT/ PRESTORM
MAIN2 INPUT
RUNOFF INPUT
MAIN2 WATER DEMAND MODEL
STORMWATER RUNOFF MODEL
WATER DEMAND DATA FOR MODEL YEAR
RUNOFF FLOWS & LOADS FOR MODEL YEAR
CONSTANT SPLIT FACTORS
UNSEWERED RUNOFF
FIXSEWER
SPLIT
FLOWS & LOADS TREATED AND UNTREATED
CORRECTED WATER DEMAND DATA FOR MODEL YEAR
MUNMATRE
SEWERED RUNOFF
A
CONSTANT SEWAGE FACTORS
SEWAGE
MAXIMUM AVERAGE PEAK WATER DEMAND
MANUAL SEWAGE FACTORS
SEWAGE LOADS & FLOWS FOR MODEL YEAR
TREATMENT
COMBINED TREATED SEWAGE FOR MODEL YEAR
AVERAGE MAX. LOADS PHOSPHORUS NITROGEN BOD
A
A
MANUAL DATA
ESTUARY HYDRODYNAMIC MODEL
FLOW RATES FOR ESTUARY SEGMENTS
MANUAL DATA
ESTUARY QUALITY MODEL
CONSTITUENT CONCENTRATIONS FOR ESTUARY SEGMENTS
OPTIONAL GRAPHICS

FIGURE 1. FRAMEWORK MODEL STRUCTURE

The model chosen for use in the Community Development Component and described here, is the EMPIRIC Activity Allocation Model. It distributes forecasted population and employment into Policy Analysis Districts (PADS) from which projections useful in many planning programs can be drawn. Different geographic areas of importance to air quality planning, transportation planning, as well as water resources planning are extracted from the projections of the Community Development Component. Alternate models that might be used in the community development component appear in Appendix A.

For the purposes of water resources planning, the forecasts were aggregated into 50 planning units that could be allocated to watersheds, water services areas, and sewage service areas. Water demand was then estimated for these planning areas by day, maximum day and peak hour and category of use; residential and commercial, industrial demand by employment category and public and unaccounted uses. The planning areas were aggregated to water service areas to summarize future water demand for a specific utility. Water demand estimates were translated directly into uninfiltrated residential and commercial sewage flow by the Sewage Generation Component. Infiltration was calculated exogenously based on the amount of developed land estimated by the Community Development Component. The estimates needed for projecting the hydraulic loads sewage from each district will impose on treatment plants.

Both the uninfiltrated residential and commercial sewage flows were multiplied by user-specified pollutant concentrations allowing the program to be tailored to local industrial conditions to provide estimates of total sewage pollutant load by parameter.

The Community Development Component, the source of population and growth forecasts used in projecting sanitary waste generation, is also used to project stormwater runoff.

From a data file, in "PRESTORM" EMPIRIC outputs of population and employment for each pad are assigned to watersheds in proportion to the fractions of area. This interface program also adds the input of the user's choice of storm to be simulated. The dry period preceding a storm is used to calculate the pollutant accumulation eligible for washoff, and the succeeding dry period is calculated to show the time possible flow retention and stormwater treatment devices may be permitted to operate at a constant rate to treat the surge of stormwater.

The simulation of a storm is completed by the EPA Stormwater Management Model and the resultant runoff summarized by a program called "Split" which divides that portion of the runoff flow and load that will be discharged directly in the estuary, from that which will be simulated as treated in the Waste Treatment Management Component.

The stormwater flows can be similated as treated in the Waste Treatment Management Component by removing a user-specified portion of the pollutant loads. The stormwater flows are then combined with simulated flows of sewage when they are discharged into the estuary.

The Waste Treatment Management Component aggregates sewage flows and loads into user-specified sewage service areas, and applies a user-specified removal efficiency to each pollutant to simulate the application of technology such as an advanced waste treatment. Flow to treatment plants due to stormwater runoff through combined sewer systems can also be simulated.

The effluent from the Waste Treatment Management Component and the additional stormwater flows and loads via the natural drainage system from the Stormwater Runoff Component are input via the Pre-estuary model to the Estuary Hydrodynamic Subprogram of the Receiving Water Component to project water quality.

Output from the Hydrodynamic Subprogram is used directly by the Estuary Quality Subprogram which calculates the dissolved oxygen level for each segment of the estuary over an entire tidal cycle. Output from the Estuary Quality Subprogram consists of estimates of various parameters for selected intervals of the 24-hour total cycle, usually one of the two-hour periods.

UTILITY OF THE FRAMEWORK MODEL AND POST COMPUTATIONAL ANALYSIS

The previous uses of the Framework Model are described in the first chapter of the "FRAMEWORK Water Resources Planning Model Technical Summary"[1] previously published by COG. The uses noted there include:

- Simulations for environmental impact statements
- Regional water demand projections
- Analysis of water conservation measures
- Estimating combined sewer overflow impacts
- Sewage Flow Estimates
- Non-point source impacts of urbanizing watersheds tributary to water supplies

Other uses to which the Framework Model and post computational analyses might be put in the regional planning process are discussed in more detail below. Special references are made to the provisions of PL 92-500, the Federal Water Pollution Control Act Amendments of 1972 (referred to as the "Act" and by specific section). It should be stressed that many of the uses of the Framework Water Resources Planning Model in the regional planning process show that each component or element of this model can be used independently or they can be linked, as was done in the full Framework Model.

Identifying Future Development Patterns

The Framework Model physical simulations begin with the Community Development Component, which, for metropolitan Washington, includes as the basic computation tool the EMPIRIC Activity Allocation Model.

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[1] C.S. Spooner, et al., Technical Summary of the Framework Water Resources Planning Model (Washington, D.C.: Metropolitan Washington Council of Governments, 1974), p. 3.

EMPIRIC is designed to distribute regional "control totals" of future households and employment among a set of small sub-areas based on alternative public policies and market forces. It is important to note that the Framework Model does not provide forecasts of the control totals, but only distributions of these totals. The forecasted regional growth, heavily driven by employment trends, migration rates and family size is one of the many initial data items required for the model. The Community Development Component distributes expected growth to small areas as the first step in the Framework analysis. Subsequent estimates of water needs, sewage generation and treatment, and non-point source generation can yield assessments of the water resource impacts of the development patterns represented by the small area distributions. Alternate development patterns can be simulated using the model by rerunning the component with different land use assumptions, different statements of accessability to transportation, or perhaps, by prohibiting growth in certain areas. Another process of testing patterns of community development patterns could involve overriding the Community Development Component output in both INTERFACE4 and PRESTORM (by producing a new population, households, and employment by watershed) to produce future small area projections reflecting different types of growth, different intensities of growth (density of development such as apartments or single family homes or different floor-area ratios) and different timing of growth.

Regional Analysis of Wastewater Treatment Efficiencies

Differences in wastewater treatment efficiencies can be easily tested by the Framework Model. The model does not suggest which efficiency ranges are realistic or affordable, but it does not provide a method of analyzing alternate discharge points, alternate discharge quantities, the effects of the discharge given different assumed river flows including flows diminished by water demands. The model can also analyze the effects of the discharge given adherence to abatement schedules for other sources of pollution in the estuary.

Regional Analysis of Non-Point Source Controls

Non-point source contributions of pollution can be estimated using the Stormwater Management Model (SWMM) through the Framework Model. Essentially all the advantages or disadvantages of the use of SWMM, or a substitute for it, in the storm-water runoff component would apply to Framework. Because the SWMM and its alternates are undergoing constant change, the most current literature citing their comparisons should be consulted.

The importance of these models, when applied in the Framework Model chain, is that the assumptions concerning community development used to drive them is consistent with those used to project related impacts on water supply and wastewater generation. A water quality management technique is directly measured by exercising the Stormwater Component of the Framework Model to estimate future runoff, and then by simulating alternative control strategies such as stormwater storage or treatment in the Waste Treatment Management Component. Additional models, not now part of FRAMEWORK, may be needed to estimate contributions from soil erosion and stream channel enlargement.

Regional Analysis of Water Demand Reduction Systems

The Water Demand Component of the Framework Model identifies various categories and subcategories of water use. These can be further analyzed in two ways through post computational analyses. The first technique is to establish a better understanding of average uses within major subcategories such as domestic in-house use. This has been done in the Metropolitan Washington area where plumbing fixtures in the home have been assigned further allotments of domestic in-house use.

A comparison of water consumption rates in currently used fixtures and the new consumption rates recommended in the amended sections of plumbing codes provides some concept of the potential water conserving effects of those amendments. Such a comparison is shown in Table 1. The consumption figures shown for existing fixtures are the lower figures of the consumption range for the respective fixture and can be considered to be as much as three to five gallons in many instances.

TABLE 1

COMPARISON OF WATER CONSUMPTION RATES[2]

Fixture	Low Estimates For Existing Fixtures	Specified By New Amendments
Water Closets	5 gals./flush	3-½ gals./flush
Urinals	4 gals./flush	3 gals./flush
Shower Heads	4 gals./minute	3 gals./minute
Faucets	4-½ gals./minute	4 gals./minute

While Table 1 applies to fixtures in proper operating condition, it does support the assumption of overall conservation factor of about 20 percent. This 20 percent figure is further supported by the Washington Suburban Sanitary Commission's Report on the Cabin John Drainage Basin Program which listed reductions in water consumption ranging from 12 percent to 30 percent with the majority in the 20 percent to 25 percent range. In addition, the more conservative figure of 20 percent allows several percentage points lee-way to account for the vagaries of human behavior.

The effect of savings in this component of the regional water demand becomes substantial when applied to total future water demand projections. Using residential demand figures and limiting the projections to residential use, analyses have shown that the projected increased demand for the year 1992 can be reduced by between 19 and 25 MGD, assuming that the increased demand is met in newly built residential construction where revised codes will be enforced.

The second form of post computational analysis involves the analysis of water billing records to determine whether there are users of significantly more water than projected by the model. Such uses may be singled out for more detailed analysis of opportunities for demand reduction or some form of recycling.

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[2] Report the Use of Regional Plumbing Codes to Effect Water Conservation (Washington, D.C.: Metropolitan Washington Council of Governments, 1973)

Evaluating Waste Load Allocations

An important requirement under Section 303(e) of the Act is the establishment of pollutant load allocations within the major water bodies of a region. This is normally done by starting with previous decisions on control technology, or assessments of maximum pollutant loads allowable within water quality standards. The estuary model, which serves as the Receiving Water Component of the Framework Model, was developed for what became the U.S. Environmental Protection Agency in 1969 and used to establish effluent limits which are the basis for the current expansion and upgrading of treatment plants discharging to the upper Potomac Estuary. This estuary model has been revised and improved by MWCOG for use in the Framework Model, and could be exercised to evaluate other load allocation schemes to meet the Section 303(e) requirements. The Section 208 planning guidelines identify the testing of alternative waste load allocations as a major activity within the planning process as well. In doing this, the model can be used for both point source loads and non-point source loads and can evaluate the influence of water supply withdrawals on natural flow conditions used to estimate maximum allowable loads.

Evaluating Cost-Effective Alternatives

The Framework Model does not contain cost estimating submodels, but it does present a method for distinguishing between alternatives on the basis of cost effectiveness.

Section 212(2) of the Act provides that Federal construction grants can only be made for systems which are determined by the U.S. Environmental Protection Agency to be "cost-efficient" as defined by EPA cost-effectiveness guidelines.[3] The EPA guidelines indicate that:

> The most cost-effective alternative shall be the waste treatment management system determined from the analysis to have the lowest present worth and/or equivalent annual value without overriding adverse non-monetary costs and to realize at least identical minimum benefits in terms of applicable Federal, State, and local standards for effluent quality, water quality, water reuse, and/or land and subsurface disposal.

In the Framework Model the benefits are measured in terms of water quality above standards. This approach seems appropriate to 208 Areawide planning in areas where segments of waterways have been designated "water quality limited." This designation applies to areas in which the application of best practical waste treatment technology to point sources alone will not assure water quality within standards. It is in these areas that nonpoint source controls must be considered along with more advanced forms of wastewater treatment and non-structural measures. The models contained within the Framework Model chain offer a mechanism to compare treatment techniques from the perspective of water quality. The "capability" of the group of treatment techniques in an areawide water resources management strategy has been defined as the extent of a constituent concentration of less than or equal to a stated constituent concentration (the standard) for greater than or equal to a stated duration.[4]

The measured extent selected for investigation is the length of estuary affected in kilometers because it represents a barrier to the movement of aquatic life and serves as a measure of the potential aesthetic effects from degraded water quality. A 96-hour duration was chosen so that the "capability" of each alternative could be compared if desired with 96-hour median tolerance limit data for both aquatic species and the associated species in their food chain.

Probability of Occurrence of Simulated Conditions

To perform a simulation using the Framework Model, assumptions must be made concerning such conditions as the expected Potomac River flow entering the region, the expected storm flow, the expected water demand withdrawals, the expected community development pattern, the reliability of treatment works to perform as simulated, and other conditions.

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[4] Charles S. Spooner, John Promise, and Philip H. Gordon, A Demonstration of Areawide Water Resources Planning (Washington, D.C.: Metropolitan Washington Council of Governments, 1974), p. 144.

The product of each of these event probabilities, if one assumes the events are independent, is the joint probability of occurrence of all of these events during the same time period.

The Framework Model contains a single event stormwater model that makes the determination of joint probabilities necessary. The alternative to single event models, continuous simulation models, allow the joint probability of these complicated, and realistically interrelated events to be determined empirically. Such flexibility adds a significant dimension to the model chain as a planning tool and, the absence of this feature is a significant drawback to the model chain in its present state.

Comparison of "Effectiveness" of Areawide Strategies

The product of the "joint probability of occurrence" and the "capability" is the expected "effectiveness" of an areawide water resources management strategy. This can be expressed as:

$$\text{Effectiveness} = P(O) \times C$$

Where P(O) is "joint annual probability of occurence" of conditions upon which the simulation was based. The value "C", is the "capability" of the areawide water resources management strategy, a measure of how well the strategy might work under the conditions modeled.

Thus, the term "effectiveness" becomes a composite of the extent, duration, constituent concentration, and joint annual probability of occurrence of the receiving water's response to alternative water resources management strategies.

Of particular significance is that the expected "effectiveness" term provides a link between bioassay results used to evaluate the toxicity of selected chemical constituents of physical parameters to aquatic species which are expressed as a 96-hour-median-tolerance limit, TL_m or TL_{50}. This link is important because it relates the alternative water resources management strategies to their effects on shellfish, fish, and wildlife which are required to be protected by the Federal Water Pollution Control Act Amendments of 1972.

Cost Estimating

Local governments and their engineering consultants have extensive experience in estimating and comparing the direct costs of proposed capital facilities using methods long known to engineering economics and specified in Federal Cost-effectiveness analysis guidelines.[5,3] Direct costs consist of *both capital* construction costs and annual costs for operation, maintenance, and repair, with the latter divided between fixed annual costs and costs which would be dependent on the annual quantity of wastewater processed. The cost of an alternative water resources management strategy is computed by discounting its costs over the selected planning period to "present worth values" or the "average annual equivalent values." Alternative systems are then compared by ranking the estimated present worth values, or used to identify where estimated values are identical within the accuracy of the analysis. The approach is relatively straightforward once the appropriate interest rate and planning period are selected, although there may be a need to give special treatment to elements of operating costs that are projected to inflate in cost at a rate well above any inflation experienced by the rest of the economy. This can be done by discounting them in present worth analysis at a rate less than that chosen for other items of cost. The cost of chemicals, fuels, or power may qualify for such treatment in present value analysis.

The total planning period capital cost element requires the following information: the total capital cost at a stated cost index, the length of the cosntruction period, and the life of the capital structure.

Operation and maintenance costs are divided into a fixed and variable portion with the variable portion further divided into a base component and a growth component. Thus the elements of operation and maintenance cost are a fixed element, a variable-base element, and a variable-growth element. The total planning period fixed operations and maintenance cost element requires an estimate of the fixed annual operations and maintenance cost at the end of the planning period, and is therefore based on the design capacity at the end of the planning period.[4]

The total planning period variable operations and maintenance cost element requires an estimate of the annual variable operations and maintenance costs. These are based on the amount of growth in used capacity of each device during the planning period and on the above-mentioned variable operations and maintenance cost per unit capacity for each device evaluated at the midpoint of the planning period.

Most water quality management alternatives chosen in the past have been capital-intensive, thus lending themselves to straightforward engineering economic analysis. As more comprehensive water resource management strategies are considered, it will be necessary to consider such things as flow reduction devices and use of pricing to reduce water consumption. These programs do not fit easily into conventional cost analyses. Therefore, the framework must be designed to permit calculation and comparison of the costs associated with these alternatives as well.

Cost Effectiveness Determination

The cost-effectiveness of a strategy is a statement of both its costs and effectiveness as defined above. Comparisons between strategies using simple graphs of these quantities have been shown.[4]

DESCRIPTION OF MODEL COMPONENTS

THE 'EMPIRIC' ACTIVITY ALLOCATION MODEL

Purpose

"EMPIRIC" is one of a family of regional planning models, which are referred to generically as "activity-allocation" formulations. It is designed to perform three major functions:

- To allocate regionwide projections of future population, employment and land use growth between a set of smaller subregions or districts, based upon exogenously specified regional planning policies;
- To estimate the probable impact of alternative planning policy decisions on the future distribution of regional growth; and
- To provide an analytical foundation for the evaluation and coordination of planning-policy decisions in a variety of different functional areas.

Program Description

The EMPIRIC model was developed for COG by a consultant and is documented in detailed reports[6] resulting from his work. The model is broken down structurally into four major components which are the simultaneous equation module, the land consumption module, other submodels, and the forecasting module.

The first module consists of a set of simultaneous, linear equations relating projected changes over time in the subregional distribution of population and employment one to the other, to their original distribution in some base-year, and to the effects of selected planning policies implemented over a given growth interval. The outputs of these equations are typically expressed as estimates of the future numbers of households within each subregion, broken down by income-level and type, together with equivalent estimates of future employment by place-of-work, broken down by industry type or land use classification.

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[6] Peat, Marwick, Mitchell, and Co., "EMPIRIC" Activity Allocation Model: Application to the Washington Metropolitan Region (Washington, D.C.: Metropolitan Washington Council of Governments, 1972)

These initial population and employment projections are translated into equivalent changes in land use for each subregion via a second "land-consumption" module. This model accepts as input the outputs of the simultaneous-equation model, together with the existing distribution of land uses in each subregion in the given base-year and a range of permissible future development densities. It generates as output updated estimates of land use acreages, broken down by type, within each sub region.

A third module, consisting of a set of supplementary submodels and also accepting as input the outputs of the simultaneous equation model, operates in parallel with the land-consumption model. These submodels are designed both to break down the initial set of subregional populations projections into their equivalent, component distributions of population by age, household size or number of workers/household, etc., and also to yield estimates of supplementary employment levels for employment categories not included in the simultaneous equation model. These typically include a number of marginal employment classes, representing only small proportions of total regional employment, such as "Construction" or "Mining".

These three components are calibrated in parallel using subregional "activity (i.e., population and employment) and land use data collected for two points in time, the COG application used inventories spaced eight years apart, together with parallel data on the planning policies implemented during the same time period. Typical policy inputs which may be incorporated within the calibration process include regional transportation and utility-system improvements; zoning, development and open-space controls; environmental and conservation standards; or regional housing and employment location policies.

They are then linked together with a fourth "forecast-monitoring" module into a single forecasting chain, designed to yield recursive estimates of the future subregional distribution of activity and land use for years into the future, with the forecast for each year building on that for the preceding year. Within this chain, each forecast is designed to be conditional both upon a presumed "regional total" of population and employment for the region as a whole, and also upon the pursuit of a particular mix of future regional planning policies over the forecast interval. In order to use the model for forecasting the analyst must, therefore, specify in advance the projected levels of region-wide population and employment growth for each forecast year, and also identify one or more "scenarios" of projected future planning policies for use as input to the forecasting process.

Operationally, such scenarios are constructed in two parts. For those policy measures incorporated as "direct variables" within one of the calibrated modules, the analyst must simply specify the future value of the variable for each subregion and each forecast year. This process, clearly, is necessarily limited to those policies which exerted a significant influence on the pattern of growth over the calibration period. All other policies must be treated somewhat differently, as "indirect constraints upon the forecasting process."

Such constraints are invoked in part through the land consumption module and in part via the set of forecast-monitoring routines outlined above. In concert, they permit the analyst to constrain the initial set of forecasts by pre-specifying minimum or maximum levels of activity in any subregion, specifying proportional mixes of activity types or restricting particular areas of land to specific types or densities of development.

In its simplest mode of operation, the model may be used to generate one single chain of forecasts based on one single policy scenario. Alternatively, by varying the mix of policy inputs for particular forecast years or particular subregions - i. e., by creating a set of alternative scenarios - it may be used to test the probable impact of alternative policy mixes on the future pattern of regional growth.

A typical set of model outputs is summarized on the following pages.

Output Available from Community Development Component (EMPIRIC)

For each Policy Analysis District and each Forecast Year Eastimates of:

Family Households In Low Income Quartile
Family Households in Low-Middle Income Quartile
Family Households in Upper-Middle Income Quartile
Family Households in Upper Income Quartile
Unrelated Individual Households
Employment in Manufacturing, Transportation, Communication and Utilities

Employment in Retail and Wholesale
Employment in Financial, Insurance, Real Estate and Services
Employment in Government
Employment in Aricultrue and Construction

POPULATION by Age
- Under 5 years
- 5 - 14
- 15 - 19
- 20 - 29
- 30 - 49
- 50 - 64
- 65 and Over

HOUSEHOLDS by Size
- 1 Person
- 2 Persons
- 3 Persons
- 4 Persons
- 5 or more Persons

HOUSEHOLDS by:
- Single-Family Households
- Multi-Family Households

LAND USE by Type
- Residential
- Industrial
- Commercial
- Intensive Institutional
- Extensive Institutional
- Parks and Open Space
- Vacant
- Residential (incl. Streets)

EMPLOYMENT by LAND USE
- Residential Land
- Commercial Land
- Institutional Land
- Agricultural and Vacant Land

EMPIRIC Availability

The EMPIRIC model was developed by, and is available from Peat, Marwick, Mitchell & Co., 1025 Connecticut Avenue, N.W., Washington, D.C., 20036. Information on its application to the Metropolitan Washington Area can be obtained from the Metropolitan Washington Council of Governments, 1225 Connecticut Avenue, N.W., Washington, D.C. 20036.

INTERFACE4

PURPOSE

The purpose of the INTERFACE4 program is to join the model which predicts community development alternatives with the model which predicts water demand. Because over 5000 data elements are required to operate the Water Demand Component for each combination of development plan and forecast year, A computer program (INTERFACE4) was developed to manage this data. Appropriate EMPIRIC output from the Community Development Component is aggregated into planning units, and then into water service areas, and reformated for direct input to MAIN II, the Water Demand Component.

INTERFACE4 selects appropriate EMPIRIC output data, aggregates EMPIRIC and constant data into matrix format by water service areas, and arranges data into the format required by the MAIN II model. INTERFACE4 produces MAIN II input both in printed and computer readable form, and prints an optional matrix (ZMAIN) that can be altered and used again as input to INTERFACE4 in preparation for subsequent MAIN II runs. This optional ZMAIN MATRIX FILE enables the user to maintain complete MAIN II input data sets from each modified run of the INTERFACE4 program, which might result from considering different development alternatives or different forecast years in the EMPIRIC Model, without having to duplicate large card decks.

CHARACTERISTICS OF OPERATION

Language IBM FORTRAN IV (G Level)

Region Program size is 190K. Actual region size at time of execution is dependent on the number of input data sets and their associated block sizes. Size required for documented runs was 275K.

PROGRAM DESCRIPTION

The user, through a series of program control cards, can modify the values of the MAIN II input data set and select the input and output for each of the INTERFACE4 programs. The two sources of input data for the INTERFACE4 program are the EMPIRIC File, as modified by the I4EMP subroutine of INTERFACE4, and the ZMAIN MATRIX FILE, which is the output from a previous INTERFACE4 run. The user, through a series of cards, is able to select the input data required for each run.

The control card stream is read and verified for proper order and processed as follows: The first card in the stream, which must be the TITLE CARD is read and printed. The next card, CARD TYPE #1, specifies the type of input (EMPIRIC or ZMAIN MATRIX FILE, created from a previous INTERFACE4 run), and a FORTRAN unit number for the location of the selected file, and the number of planning units to be used in the run. If the CARD TYPE #1 specifies the ZMAIN MATRIX FILE as input, the file is read into the ZMAIN MATRIX, area of the program. The program then searches for and reads all optional TYPE #2 cards. These cards, if present, enable the user to insert new values directly into the ZMAIN MATRIX with constant data not found in the EMPIRIC data. When this task is completed the program will read a TYPE #3, which will call the subroutine I4EMP in to modify the EMPIRIC DATA. The CARD TYPE #3 contains the FORTRAN unit number of the EMPIRIC file to be used and the total number of Area Allocation Cards that are to follow in the Program.

the following functions are performed by the I4EMP subroutine:

1. Reads and prints the Card Type #3A, Area Allocations Cards, and stores the data in tables. These cards enable the user to convert the Empiric Policy Analysis Districts to various area systems schemes. A percentage of each PAD is then allocated to the new system, in this case a (water service area) planning unit.

2. Reads and prints the two Card Type #3B, Sewer Coefficient/Quartile Index Cards, and stores the values in a table. The coefficients are multiplied by one of the income quartiles of households, selected by the corresponding quartile index, to yield the number of households by value range for metered water and flat rate water service.

3. Reads and prints the two Card Type #3C, Index Variable Cards. These cards equate the 16 data categories needed for the computation of the MAIN II input to the corresponding data categories in the EMPIRIC file for the desired forecast year.

4. Reads the EMPIRIC File, selects the proper variables by the Index Variables Cards and accumulates the variables by planning unit through the use of the area allocation cards. When the EMPIRIC file has been processed the computations are then performed for the MAIN II Data. Households, by seven home value ranges for both metered and flat rate water, are computed using the coefficients and quartile index table. Persons per household, households per residential acre, number of employees by five major employment categories, total population and population by two age groups are stored in the ZMAIN MATRIX.

Control is returned to the main program when these tasks are completed by the I4EMP subroutine.

The program reads the control card stream and searches for the optional CARD TYPE #4. This card, if present, enables the user to override the MAIN II Data elements that were computed from the EMPIRIC data and insert user selected values into the ZMAIN MATRIX. CARD TYPES #2 and #4 are used to modify specific cells in the ZMAIN MATRIX. The matrix contains a Planning Unit number, which can vary from 1 to 200, as one dimension and the MAIN II data variable number, which refers to one of the 105 MAIN II parameters, as the second dimension.

The next card, CARD TYPE #5, provides the user with three different output options.

1. Print the MAIN II input data set. This option lists the values in the ZMAIN MATRIX in the card format that is required by the MAIN II program.

2. Transfer the MAIN II input data set, A computer readable storage device. The MAIN II file is written to a storage device, either tape or disk, to be used as direct input to the MAIN II program.

3. Write the ZMAIN MATRIX data set. The ZMAIN MATRIX is the alternate input to INTERFACE4. This matrix can be updated using CARD TYPE #2 and #4 to produce a new MAIN II input set at a significant savings in computer time.

After all the output operations have been performed the final card in the control card stream should be a CARD TYPE #9. A normal end of job message will be printed and the run will then terminate. The job will terminate at any point in the program if the program encounters any errors or unidentified card types in the control card stream.

SAMPLE SETUP - See Input-Output Flow Chart.

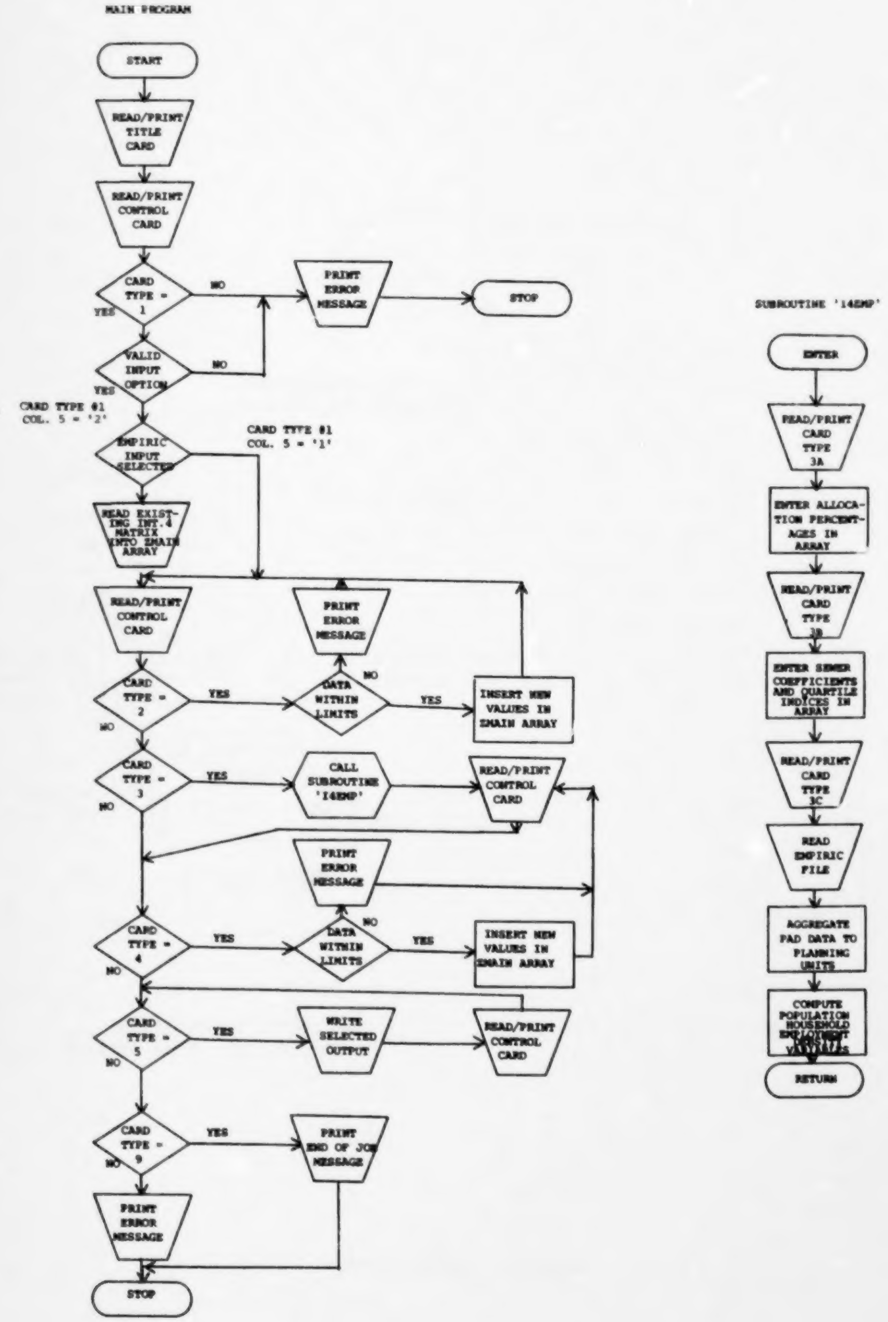
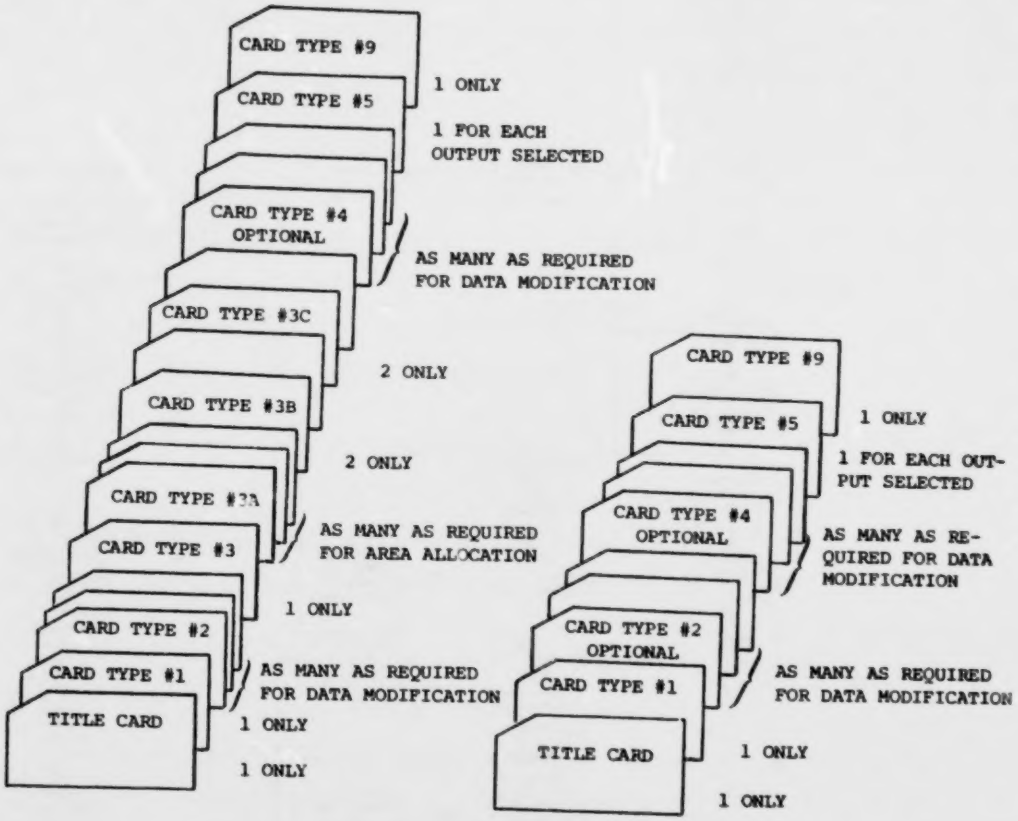

MAIN PROGRAM
START
READ/PRINT TITLE CARD
READ/PRINT CONTROL CARD
CARD TYPE = 1
NO
YES
PRINT ERROR MESSAGE
STOP
VALID INPUT OPTION
NO
YES
CARD TYPE #1 COL. 5 = '2'
EMPIRIC INPUT SELECTED
CARD TYPE #1 COL. 5 = '1'
READ EXISTING INT.4 MATRIX INTO ZMAIN ARRAY
READ/PRINT CONTROL CARD
PRINT ERROR MESSAGE
CARD TYPE = 2
YES
DATA WITHIN LIMITS
NO
YES
INSERT NEW VALUES IN ZMAIN ARRAY
NO
CARD TYPE = 3
YES
CALL SUBROUTINE 'I4EMP'
READ/PRINT CONTROL CARD
NO
PRINT ERROR MESSAGE
CARD TYPE = 4
YES
DATA WITHIN LIMITS
NO
YES
INSERT NEW VALUES IN ZMAIN ARRAY
NO
CARD TYPE = 5
YES
WRITE SELECTED OUTPUT
READ/PRINT CONTROL CARD
NO
CARD TYPE = 9
YES
PRINT END OF JOB MESSAGE
NO
PRINT ERROR MESSAGE
STOP
SUBROUTINE 'I4EMP'
ENTER
READ/PRINT CARD TYPE 3A
ENTER ALLOCATION PERCENTAGES IN ARRAY
READ/PRINT CARD TYPE 3B
ENTER SEWER COEFFICIENTS AND QUARTILE INDICES IN ARRAY
READ/PRINT CARD TYPE 3C
READ EMPIRIC FILE
AGGREGATE PAD DATA TO PLANNING UNITS
COMPUTE POPULATION HOUSEHOLD EMPLOYMENT DENSITY VARIABLES
RETURN

FIGURE 2. INTERFACE 4 PROGRAM FUNCTION FLOWCHART


CARD TYPE #9
1 ONLY
CARD TYPE #5
1 FOR EACH OUTPUT SELECTED
CARD TYPE #4 OPTIONAL
AS MANY AS REQUIRED FOR DATA MODIFICATION
CARD TYPE #3C
2 ONLY
CARD TYPE #3B
2 ONLY
CARD TYPE #3A
AS MANY AS REQUIRED FOR AREA ALLOCATION
CARD TYPE #3
1 ONLY
CARD TYPE #2
AS MANY AS REQUIRED FOR DATA MODIFICATION
CARD TYPE #1
1 ONLY
TITLE CARD
1 ONLY
CARD TYPE #9
1 ONLY
CARD TYPE #5
1 FOR EACH OUTPUT SELECTED
CARD TYPE #4 OPTIONAL
AS MANY AS REQUIRED FOR DATA MODIFICATION
CARD TYPE #2 OPTIONAL
AS MANY AS REQUIRED FOR DATA MODIFICATION
CARD TYPE #1
1 ONLY
TITLE CARD
1 ONLY

INPUT OPTION #1

PROCESS AN EMPIRIC DATA SET

INPUT OPTION #2:

PROCESS AN EXISTING INTERFACE4 ZMAIN MATRIX DATA SET

FIGURE 3. SAMPLE SETUP FOR INTERFACE4

DATA SPECIFICATIONS

Input Description

Input to the INTERFACE4 program is a computer generated input data file and a manually coded series of user control cards. One of two computer generated inputs to INTERFACE4 are:

1. EMPIRIC Data Set.

   A data record for each EMPIRIC Policy Analysis District, is generated by the EMPIRIC Activity Allocation Model described previously. The EMPIRIC data set must be used initially, but as the program is rerun in considering different management alternatives and different forecast years, the second input format, the ZMAIN MATRIX, is more useful.

2. ZMAIN MATRIX FILE

   This is the optional output of a previously run INTERFACE4 program. This file contains one record for each planning unit, which contains all the data needed to construct MAIN II input for that planning unit.

The control cards needed for the program operation have no default values associated with any of the parameters. Unless otherwise noted, all parameters are required for proper execution of the program. The control cards for the program operation must be in the following order:

CARD #1

Type:	Title Card
Number:	One card only
Purpose:	Specify run title
Format:	(20A4)

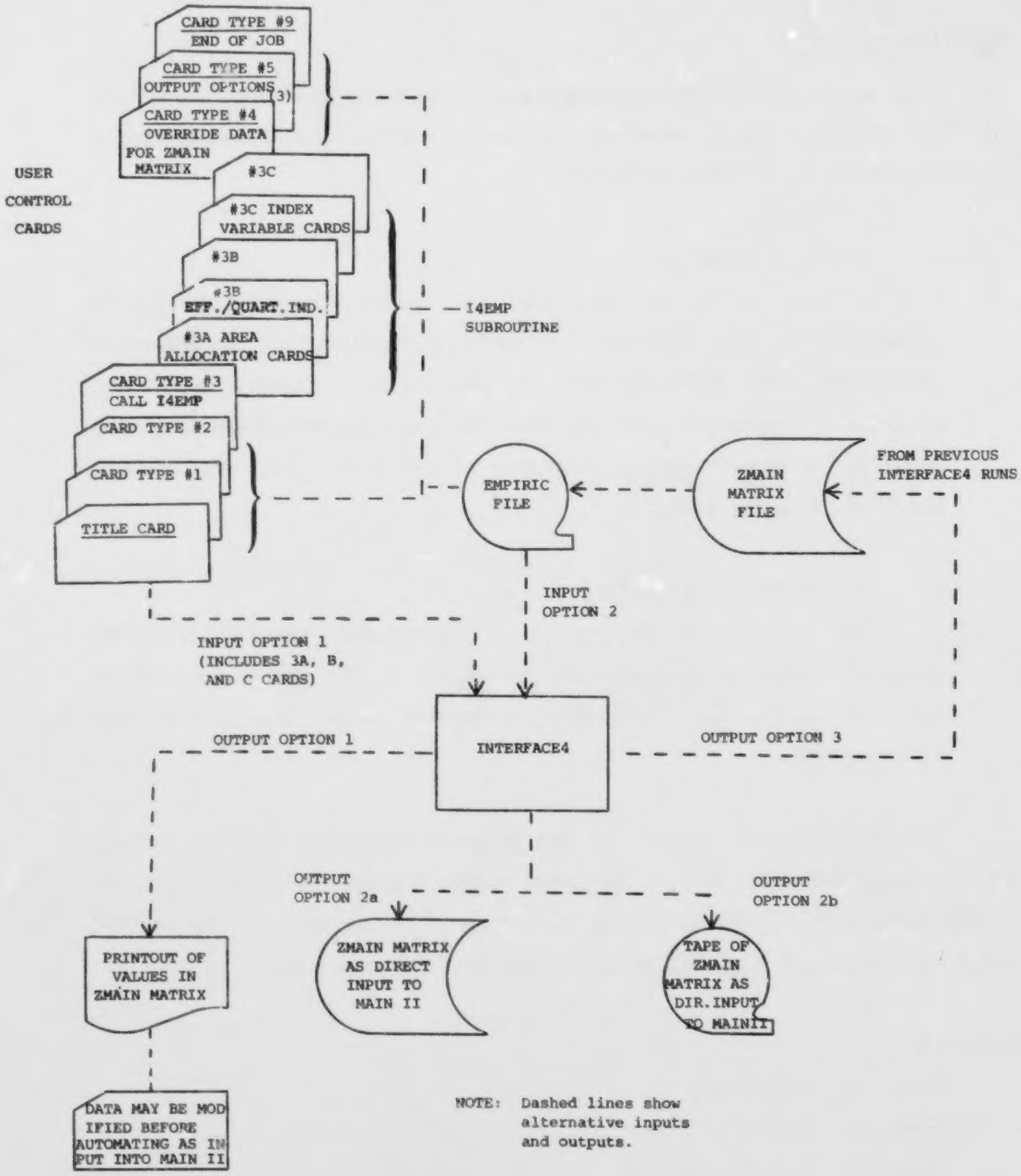

CARD TYPE #9
END OF JOB
CARD TYPE #5
OUTPUT OPTIONS(3)
CARD TYPE #4
OVERRIDE DATA
FOR ZMAIN
MATRIX
USER
CONTROL
CARDS
#3C
#3C INDEX
VARIABLE CARDS
#3B
#3B
EFF./QUART.IND.
#3A AREA
ALLOCATION CARDS
I4EMP
SUBROUTINE
CARD TYPE #3
CALL I4EMP
CARD TYPE #2
CARD TYPE #1
TITLE CARD
EMPIRIC
FILE
ZMAIN
MATRIX
FILE
FROM PREVIOUS
INTERFACE4 RUNS
INPUT
OPTION 2
INPUT OPTION 1
(INCLUDES 3A, B,
AND C CARDS)
INTERFACE4
OUTPUT OPTION 1
OUTPUT OPTION 3
OUTPUT
OPTION 2a
OUTPUT
OPTION 2b
PRINTOUT OF
VALUES IN
ZMAIN MATRIX
ZMAIN MATRIX
AS DIRECT
INPUT TO
MAIN II
TAPE OF
ZMAIN
MATRIX AS
DIR.INPUT
TO MAINII
DATA MAY BE MOD
IFIED BEFORE
AUTOMATING AS IN
PUT INTO MAIN II
NOTE: Dashed lines show
alternative inputs
and outputs.

FIGURE 4. INTERFACE4 INPUT-OUTPUT FLOWCHART

CARD #2

Type: Card Type #1

Number: One card only

Purpose: Specify input data set, unit number of data set, if ZMAIN MATRIX FILE is selected for input, and number of planning units for the run.

Format: (I1,1X,3(I3,1X),F10.0,2X),2(I3,1X),F10.0)

Col.	1	'1' card type entered
	2-4	Blank
	5	'1' = EMPIRIC Data set selected as input.
	6-7	Blank
	8-9	Unit number of ZMAIN MATRIX FILE use when Col. 5 = '2'.
	23-25	Number of planning units for the run.
	26-80	Blank

CARD #3

Type: Card Type #2

Number: As many as needed to insert user supplied data. (optional card)

Purpose: To enter constant MAIN II values into the ZMAIN MATRIX. Constant data would be items such as year, values ranges, and other MAIN II values that are not computed from the EMPIRIC data.

Format: (I1,1X,3(2(I3,1X),F10.0,2X),2(I3,1X),F10.0)

Col.	1	'2' card type entered
	2	Blank
	3-5	Planning unit number
	6	Blank
	7-9	MAIN II data element number
	10	Blank
	11-20	Value to be inserted in ZMAIN MATRIX
	21-22	Blank
	23-25	Planning unit number (value #2)
	26	Blank
	27-29	MAIN II data element number (value #2)
	30	Blank

31-40	Value to be inserted in ZMAIN MATRIX
41-42	Blank
43-45	Planning unit number (value #3)
46	Blank
47-49	MAIN II data element number (value #3)
50	Blank
51-60	Value to be inserted in ZMAIN MATRIX
61-62	Blank
63-65	Planning unit number (value #4)
66	Blank
67-69	MAIN II data element number (value #4)
70	Blank
71-80	Value to be inserted in ZMAIN MATRIX

As many of these cards as needed for modification can be inserted into the program.

CARD #4

Type: Card Type #3

Number: One only - must be present if CARD TYPE #1 Col. 5 = '1'

Purpose: Specify the unit number of the EMPIRIC data set and the number of Area Allocation Cards that follow.

Format: (I1,1X,3(I3,F10.0,2X),2(I3,1X),F10.0)

Col.	1	'3' card type entered
	2	Blank
	3-5	Unit number of EMPIRIC data set
	6	Blank
	7-9	Number of CARD TYPE 3A's Area Allocation Cards, that follow

CARD #5

Type: CARD #3A Area Allocation Cards

Number: The number of cards in this section must equal the value coded in Col. 7-9 of CARD TYPE #3. The program allows a maximum of 200 allocations

Purpose: To distribute a certain percentage of each Policy Analysis District to a planning unit.

Format: (9X,3(I3,1X,I3,1X,F7.0,5X),11X)

Col.	1-9	Blank
	10-12	Planning unit number

CARD #6

Type: CARD #3B Meter-Flat Sewer Coefficients/Quartile Index Card

Number: Two must be present if Card Type #3 is present

Purpose: The seven coefficents are multiplied by the number of households by income quartiles to yield households by home value range. The quartile index number is used to select the proper household quartile for each of the seven operations.

Format: (7F10.0,7I1,3X) First card for Meter Water, Second card for Flat Water.

Col.	1-10	Coefficient for value range #1
	11-20	Coefficient for value range #2
	21-30	Coefficient for value range #3
	31-40	Coefficient for value range #4
	41-50	Coefficient for value range #5
	51-60	Coefficient for value range #6
	61-70	Coefficient for value range #7
	71	Quartile index for value range #1
	72	Quartile index for value range #2
	73	Quartile index for value range #3
	74	Quartile index for value range #4
	75	Quartile index for value range #5
	76	Quartile index for value range #6
	77	Quartile index for value range #7
	78-80	Blank

CARD #7

Type: CARD #3C Index Variable Cards

Number: Two must be present if Card Type #3 is present

Purpose: To equate the 16 items used in the computation of the MAIN II values to the corresponding items on the EMPIRIC data set.

Format: 16(2X,I3) Eight pairs per card for the two cards required.

Col.	1-2	Blank
	3-5	Index number, refers to information in the EMPIRIC data set.
	6-7	Blank
	8-10	EMPIRIC variable number for four years, 1968, 1976, 1984, 1992.
	11-12	Blank
	13-15	Index number

16-17	Blank
18-20	EMPIRIC variable number
21-22	Blank
23-25	Index number
26-27	Blank
28-30	EMPIRIC variable number
311-32	Blank
33-35	Index number
36-37	Blank
38-40	EMPIRIC variable number
41-42	Blank
43-45	Index number
46-47	Blank
48-50	EMPIRIC variable number
51-52	Blank
53-55	Index number
56-57	Blank
58-60	EMPIRIC variable number
61-62	Blank
63-65	Index number
66-67	Blank
68-70	EMPIRIC variable number
71-72	Blank
73-75	Index number
76-77	Blank
78-80	EMPIRIC variable number

CARD #8

Type: Card Type #4

Number: As many as needed to insert user supplied data. (optional card)

Purpose: To insert data into ZMAIN MATRIX after the data from the EMPIRIC FILE has been modified by the I4EMP subroutine. This card will supply data to override the data items in the MATRIX. and inserted into the ZMAIN MATRIX.

Format: (I1,1X,3(2I3,1X),F10,0,2X),2(I3,1X)F10.0)

Col.		
	1	'4' card type entered
	2	Blank
	3-5	Planning unit number

6	Blank
7-9	MAIN II data element number
10	Blank
11-20	Value to be inserted in ZMAIN MATRIX
21-22	Blank
23-25	Planning unit number (value #2)
26	Blank
27-29	MAIN II data element number (value #2)
30	Blank
31-40	Value to be inserted in ZMAIN MATRIX
41-42	Blank
43-45	Planning unit number (value #3)
46	Blank
47-49	MAIN II data element number (value #3)
50	Blank
51-60	Value to be inserted in ZMAIN MATRIX
61-62	Blank
63-65	Planning unit number (value #4)
66	Blank
67-69	MAIN II data element number (value #4)
70	Blank
71-80	Value to be inserted in ZMAIN MATRIX

CARD #9

Type: Card Type #5

Number: As many as needed

Purpose: Select the types of output

Format: Same as Card #4

Col. 1 = 5 (Card Type)

Col. 3-5 = 1-Print MAIN II Input File in Card Format

2-Write MAIN II Input File to Storage Device - Input to MAIN II

3-Write ZMAIN MATRIX to storage device - Input to INTERFACE4

Col. 8-9 = Unit Number of Output Data set if Col. 3-5 = 2 or 3

Type: Card Type #9
Number: 1 only
Purpose: Signify end of control cards
Format: Col. 1 = 9 (Card Type)

Output Description

1. The MAIN II Data set can be printed and/or wirtten to a storage Device

2. The ZMAIN MATRIX, a file of all the values in the MAIN II Data set, can be written to a storage device and then used as input to subsequent INTERFACE4 runs.

3. All control cards input to the program are printed, and diagnostic messages are printed as necessary.

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EMPDA VARIABLE NUMBER	DATA ITEM	USAGE
1	# Families in Lower Inc. Quartile	INTERMEDIATE
2	# Families in Low/Middle Quartile	
3	# Families in Upper/Middle Quartile	
4	# Families in Upper Quartile	INTERMEDIATE
6	# Employees in Manu/T.C.U.	DIRECT
7	# Employees in Retail/Wh. Trade	
8	# Employees in F.I.R.E./Services	
9	# Employees in Government	
10	# Employees in Agriculture/Construc.	DIRECT
11	Acres of Residential Land	INTERMEDIATE
20	# HH of Size 1	INTERMEDIATE
21	# HH of Size 2	
22	# HH of Size 3	
23	# HH of Size 4	
24	# HH of Size 5	
25	# HH of Size 6 & Over	
28	Population 5 Years	INTERMEDIATE
29	Population 5 - 14 Years	DIRECT
30	Population 15 - 19 Years	DIRECT
31	Population 20 - 29 Years	INTERMEDIATE
32	Population 30 - 49 Years	
33	Population 50 - 64 Years	
34	Population 65 Years + Over	
39	# of Single Family HH	
40	# of Multi Family HH	INTERMEDIATE

```
ITEMP=EPA1(I)+EPA2(I)+EPA3(I)+EPA4(I)

EPAP1=EPA1(I)/ITEMP
EPAP2=EPA2(I)/ITEMP
EPAP3=EPA3(I)/ITEMP
EPAP4=EPA4(I)/ITEMP


ZMAIN(I,97)=EPA6(I)
ZMAIN(I,98)=EPA7(I)
ZMAIN(I,99)=EPA8(I)
ZMAIN(I,100)=EPA9(I)
ZMAIN(I,101)=EPA10(I)


DENS=HH(I)/EPA11(I)  ZMAIN(I,32)=DENS ZMAIN(I,59)=DENS ZMAIN(I,79)=DENS
ZMAIN(I,14)=DENS     ZMAIN(I,38)=DENS ZMAIN(I,64)=DENS ZMAIN(I,84)=DENS
ZMAIN(I,20)=DENS     ZMAIN(I,44)=DENS ZMAIN(I,69)=DENS ZMAIN(I,89)=DENS
ZMAIN(I,26)=DENS     ZMAIN(I,50)=DENS ZMAIN(I,74)=DENS
PCNT=EPA20(I)*1.+EPA21(I)*2.+EPA22(I)*3.+EPA23(I)*4.+EPA24(I)*5.

HH(I)=EPA20(I)+EPA21(I)+EPA22(I)+EPA23(I)+EPA24(I)+EPA25(I)
PEPL=PCNT/HH(I)
ZMAIN(I,60)=PEPL
ZMAIN(I,65)=PEPL
ZMAIN(I,70)=PEPL
ZMAIN(I,75)=PEPL
ZMAIN(I,80)=PEPL
ZMAIN(I,85)=PEPL
ZMAIN(I,90)=PEPL

 POPU=EPA28(I)+EPA29(I)+EPA30(I)+EPA31(I)+EPA32(I)+EPA33(I)+
*EPA34(I)
 ZMAIN(I,10)=POPU

 ZMAIN(I,95)=EPA29(I)
 ZMAIN(I,96)=EPA30(I)


QUART(1)=EPAP1*EPA39(I)  ZMAIN(I,13,=C(1)*QUART(N(1))  ZMAIN(I,37)=C(5)*QUART(N(5))
QUART(2)=EPAP2*EPA39(I)  ZMAIN(I,19)=C(2)*QUART(N(2,)  ZMAIN(I,43)=C(6)*QUART(N(6))
QUART(3)=EPAP3*EPA39(I)  ZMAIN(I,25)=C(3)*QUART(N(3))  ZMAIN(I,49)=C(7)*QUART(N(7))
QUART(4)=EPAP4*EPA39(I)  ZMAIN(I,31)=C(4)*QUART(N(4))

QUART(1)=EPAP1*EPA40(I)  ZMAIN(I,58)=C1(1)*QUART(N1(1))  ZMAIN(I,78)=C1(5)*QUART(N1(5)
QUART(2)=EPAP2*EPA40(I)  ZMAIN(I,63)=C1(2)*QUART(N1(2))  ZMAIN(I,83)=C1(6)*QUART(N1(6)
QUART(3)=EPAP3*EPA40(I)  ZMAIN(I,68)=C1(3)*QUART(N1(3))  ZMAIN(I,88)=C1(7)*QUART(N1(7)
QUART(4)=EPAP4*EPA40(I)  ZMAIN(I,73)=C1(4)*QUART(N1(4))
```

MAIN DATA ITEMS

VARIABLES

6-CDAT
10-POPU
13-NUMB-1-M
14-DENS-1-M
19-NUMB-2-M
20-DENS-2-M
25-NUMB-3-M
26-DENS-3-M
31-NUMB-4-M
32-DENS-4-M
37-NUMB-5-M
38-DENS-5-M
43-NUMB-6-M
44-DENS-6-M
49-NUMB-7-M
50-DENS-7-M
58-NUMB-1-F
59-DENS-1-F
60-PEPL-1-F
63-NUMB-2-F
64-DENS-2-F
65-PEPL-2-F
68-NUMB-3-F
69-DENS-3-F
70-PEPL-3-F
73-NUMB-4-F
74-DENS-4-F
75-PEPL-4-F
78-NUMB-5-F
79-DENS-5-F
80-PEPL-5-F
83-NUMB-6-F
84-DENS-6-F
85-PEPL-6-F
88-NUMB-7-F
89-DENS-7-F
90-PEPL-7-F
95-SKLL
96-SKLH
97-C001
98-C002
99-C003
100-C004
101-C005

CONSTANTS

1-MACH
2-LBIN
3-LIBY
4-PROJ
5-PNCH
7-LATD
8-LONG
9-CCBN
11-VALN-1-M
12-VALX-1-M
15-ANPR-1-M
16-SMPR-1-M
17-VALN-2-M
18-VALX-2-M
21-ANPR-2-M
22-SMPR-2-M
23-VALN-3-M
24-VALX-3-M
27-ANPR-3-M
28-SMPR-3-M
29-VALN-4-M
30-VALX-4-M
33-ANPR-4-M
34-SMPR-4-M
35-VALN-4-M
36-VALX-5-M
39-ANPR-5-M
40-SMPR-5-M
41-VALN-6-M
42-VALX-6-M
45-ANPR-6-M
46-SMPR-6-M
47-VALN-7-M
48-VALX-7-M
51-ANPR-7-M
52-SMPR-7-M
53-LOWV -M
54-MEDV -M
55-HIGH -M
56-VALN-1-F
57-VALX-1-F
61-VALN-2-F
62-VALX-2-F
66-VALN-3-F
67-VALX-3-F
71-VLAN-4-F
72-VALX-4-F
76-VALN-5-F
77-VALX-5-F
81-VALN-6-F
82-VALX-6-F
86-VALN-7-F
87-VALX-7-F
91-LOWV -F
92-MEDN -F
93-HIGN -F
94-HOSP
102-C006
103-C007
104-C008
105AIRP

TABLE 2. EMPIRIC VARIABLES INPUT TO MAIN II COMPUTATIONS

MAIN II WATER DEMAND COMPONENT

PURPOSE

The MAIN II system is a tool for estimating and forecasting municipal water requirements. The system itself is a set of formalized procedures which have been developed specifically for use in planning municipal water supply. The word MAIN is an acronym meaning Municipal And Industrial Needs.

Water requirements can be estimated separately for the residential, commercial/institutional, industrial, and public-unaccounted sectors of a designated urban area. Within these sectors, requirements may be further estimated for individual categories of water users, such as metered-sewered residences, flat-rate sewered residences, commercial establishments, institutions, three-digit standard industrial classification (S.I.C.) manufacturing categories, etc. Estimates are made of mean annual, maximum day, and peak hour requirements for each category.

To accomplish all of this, the MAIN II system is composed of a system of modular computer programs which solve equations that define water usage as a function of various dependent economic, social, and environmental parameters used as input data. These parameters include such items as: number of residences, by home value range, population density, price of water, sewage disposal method, number of students, number of hospital beds, geographic location of the urban area, etc.

The MAIN II system is based primarily on the research work performed at The Johns Hopkins University.[13, 14, 16] In this work, detailed studies were made of the factors that influence residential and commercial usage of water. A number of equations were derived using regression analysis and statistical techniques to relate water usage quantitatively to the factors or parameters that have the greatest influence or usage. The work of other organizations such as the Bureau of the Census and the American Water Works Association was used to supplement the Johns Hopkins University work. The MAIN II system itself was developed by Hittman Asrociates[7, 8, 9, 10].

In the context of FRAMEWORK, the water demand generated by MAIN II is a prerequisite for finding the flows of municipal wastewater. The output from MAIN II is therefore routed to a sewage generation routine where it represents the input data. MAIN II has been applied separately in several planning efforts, as tabulated by Hittman[10]. These efforts have shown MAIN II to be a flexible and comprehensive planning tool on its own.

CHARACTERISTICS OF OPERATION

Language:	FORTRAN IV Level G
Region:	Covers 200K during execution

PROGRAM DESCRIPTION

Model Calculations

Main II is structured as a series of subroutines which either manipulate the data, make computations, or edit the output data. Following is a brief description of each of these subroutines.

Control Program

Subroutine Name: MAIN Program

MAIN is the control program for the water demand model system. It controls the execution of the two input routines and calls into execution each of the computational subroutines.

Municipal Data Input Processor

Subroutine Name: REDINP

The subroutine reads in municipal data, identifies it, and stores it in the proper place in memory. Municipal data are composed of system options, municipal identification, and parameters.

Library Data Input Processor

Subroutine Name: REDCOF

This routine reads the program's library data, identifies it, and stores it. The Library contains the following industrial and climate-related data that allows the program to be tailored to area of study:

- Residential equations constants
- Residential climatic factors as a function of latitude and longtitude.
- Commercial category names
- Commercial Parameter names

  A table of each of the commercial usage coefficients for mean annual, maximum day and peak hour.
- Industry category names

  A table of each of the industrial usage coefficients for mean annual, maximum day and peak hour (latter two not available for COG region)
- Public/unaccounted category names

  A table of each of the public/unaccounted usage coefficients for mean annual, maximum day and peak hour.

In this part of the subroutine, the latitude and longitude of the urban area being analyzed are used as indices to locate the proper values of "evapotranspiration" and "precipitation".

Residential Usage Computational Program

Subroutine Name: RESDNT

This routine controls the calculation of residential water usage values and determines which table of values is to be printed. The residential water usage includes both domestic and sprinkling usage, mean annual, maximum day, and peak hour usage, are found for metered sewer and flat rate sewer areas.

The average rates of uses are found from the following set of formulas, computed for any value range of house, or apartment, i:

Domestic Use in Single-Family Households, Metered and Sewered Areas (gpd) =

$$\left[206 + 3.47 \left(\frac{\mathrm{VALN}_i + \mathrm{VALX}_i}{2000} \right) - 1.3\ \mathrm{ANPR}_i \right] \mathrm{NUMB}_i \qquad (1)$$

Sprinkling by Single-Family Households, Metered and Sewered Areas (gpd) =

$$\left[0.39\ (0.164) \left(\frac{\mathrm{DENS}_i^{\,1.26}}{0.803} \right)^{0.793} (E - 0.6P)^{2.93} \left(\frac{1}{\mathrm{SMPR}_i} \right)^{1.57} \left(\frac{\mathrm{VALN}_i + \mathrm{VALX}_i}{2000} \right)^{1.45} \right] \mathrm{NUMB}_i \qquad (2)$$

where

E = summer evapotranspiration

P = summer precipitation

Domestic Use in Apartments, Flat Rate and Sewered Areas (gpd) =

$$\left[28.9 + 4.39 \left(\frac{\mathrm{VALN}_i + \mathrm{VALX}_i}{2000} \right) + 33.6\ (\mathrm{PEPL}_i) \right] \mathrm{NUMB}_i \qquad (3)$$

Sprinkling by Apartments, Flat Rate and Sewered Areas (gpd) =

$$\left[94.0\ (0.083) \left(\frac{\mathrm{VALN}_i + \mathrm{VALX}_i}{2000} \right)^{0.553} \right] \mathrm{NUMB}_i \qquad (4)$$

Formula (4) is due to Howe et al[12], while (1), (2), (3) are from Hittman[10].

Commercial Usage Computational Program

Commercial Usage Computational Program

Subroutine Name: COMMER

This routine computes the current annual average water usage for each type of commercial/institutional establishment and the total water usage for the study area for each type of water demand - mean annual, maximum day and peak hour.

Industrial Usage Computational Program

Subroutine Name: INDSTL

This routine calculates industrial water usage values - mean annual, maximum day and peak hour usage.

Public/Unaccounted Usage Computational Program

Subroutine Name: PUBLIC

This routine controls the calculation and displaying of public/unaccounted water usage values.

Commercial, industrial, and public/unaccounted usage are computed by means of the same general formula for any category, k: Average daily use

$$\text{gpd} = \text{COEF}_j\ \text{PARA}_k \qquad (5)$$

where

COEF = usage coefficient

PARA = level of activity

according to Hittman[10].

Residential Report Generator Program

Subroutine Name: RDSPLY

This routine controls the displaying of the residential water usage values. Tables of residential water usage values can be printed for each of the two residential categories; metered,sewered and flat rate sewered.

The tables give the range of home values, number of dwelling units, the mean annual average usage and its distribution between sprinkling and domestic usage; the maximum day and peak hour usage. The amounts of summer evapotranspiration and summer precipitation are given for the study area.

Commercial Report Generator Program

Subroutine Name: CDSPLY

This routine controls the display of the commercial/institutional water usage information.

Industrial Report Generator Program

Subroutine Name: IDSPLY

This routine controls the printing of the tables of industrial water usage values for mean annual, maximum day and peak hour usage. Then a breakdown of these three usage types by industrial code (S.I.C.) and industry category is given.

Municipal Summary Report Generator Program

Subroutine Name: DISPLY

This routine prints a summary table of municipal water usage showing mean annual, maximum day and peak hour for each land use category.

Ancillary Program

Subroutine name: INITL, UNPACK

The ancillary programs perform arithmetic operations and data manipulations which are needed because of the structure and logic of MAIN II. INITL creates artificial starting values of several matrices prior to the computations. UNPACK interprets a single variable (NN) which actually consists of three separate variables.

Predicting Residential Water Usage

The principal factor influencing total annual water use in residential area is the total number of homes. In addition to the number of households, the John Hopkins study identified three other important factors which affect water use in residential areas. These are the economic level of consumers as indicated by the market value of their homes, the climate, and whether customers are metered or billed on a flat-rate basis.

A 1971 study of water and sewage rates[15] indicated that all customers served by public water systems in the Metropolitan Washington region are metered. However, since individual apartment units do not directly pay for water on a per gallon basis, the MAIN II system assumes that apartment dwellers will consume water at the same rate as flat-rate homeowners.

Thus, for the Framework Model, all owner-occupied single-family homes and townhouses are considered to be in the metered category, while all individual aparment units are considered to be in the flat-rate category. Although of lesser significance, it should be noted that households served by private systems such as wells are considered by the Framework Model to consume water as though they were metered.

According to the researchers, whether consumers are metered or on a flat-rate basis appears to have only minor influence on domestic (household) use but considerable influence on sprinkling use. However, the original flat-rate sprinkling equations in the MAIN II system were developed based on dwellings in the midwest, not for apartments in the urban east. Therefore, in the Framework Model flat-rate sprinkling equations have been modified to correspond to the relationships found by Howe and Linaweaver in 1967 and published in 1971 by Howe et al for the National Water Commission,[12] Another major factor influencing residential water demand is climate. As with flat rate vs. metered residences, climate has little effect on domestic use but a substantial effect on water used in sprinkling. The hydrologic factors found to be most important are precipitation, runoff, infiltration, root-zone storage, and evaporation. As part of the Main II system, a Library of Water Usage Coefficients was designed to contain the required climatic data for the entire United States. Therefore, the climatic data contained in this library for Washington, D.C. have been utilized.

The other major factor influencing residential water demand is the income level of the consumer. It appears that a consumer in a higher-valued area is likely to have more water using appliances and more ornamental plantings requiring sprinkling. For areas served by public sewer, the regression analysis indicated a correlation between domestic use and average market value of homes.

It was found that in areas with septic tanks for sewage disposal, economic level has little effect on domestic use, but that population density (persons per dwelling unit) accounted for almost all variations in domestic use.

For use in the Framework Model, the metered-sewered residences have been divided into seven value ranges (VALN and VALX for each range). Actual 1970 Metropolitan Washington data of single family units by these seven value ranges was first obtained in 1970 dollars. Since the MAIN II system requires that home value be indicated in 1960 dollars, the number of households in each value range was adjusted accordingly.

In a similar fashion, the flat-rate-sewered apartment units were divided into seven value ranges. However, since actual 1970 data was available for the number of households by rent (and not by the equivalent cost of the apartment unit if it were a single-family home), it was first necessary to convert from rent value to equivalent home values. The resulting value ranges were somewhat lower than those in the metered-sewered category. The ranges of values for single family units was developed from income distributions (quartiles). It was assumed that each income range would be associated with a certain range in home values. The water demand could then be computed for each value range. The derived distribution of home values was the one whose total water use was equal to the recorded demand.

Because of the flat-rate vs. metered service and the septic tank vs. sewers relationships, the MAIN II system includes submodels to estimate residential water demand by four major groupings. These are metered (water bill) and sewered, metered and septic tank, flat rate and sewered, and flat rate and septic tank residences. However, since septic tank systems are gradually vanishing in the Metropolitan Washington region, the Framework Model utilizes the first two categories only in estimating future water demands.

Another factor that influences residential water use is the cost of water. Indeed, further investigation by the Johns Hopkins researchers necessitated the reworking of the original models of residential water demand to include the influence of cost.[11]

Predicting Commercial, Institutional and Industrial Water Usage

The MAIN II system permits the commercial, institutional and industrial segments of the community to be divided into categories by type establishment or industry, and water demand to be estimated for each type. Commercial establishments include businesses of all kinds, mostly retail, which are not included in the Bureau of the Census Standard Industrial Classifications. Because of the similarity of the MAIN II computational techniques for the commercial, institutional and the industrial categories, the format of the data to be used, and the fact that there is little industry in the Metropolitan Washington region, these two categories were combined under the commercial and institutional heading.

The MAIN II system has a built-in set of 28 general purpose commercial and institutional categories. Some examples are hotels, hospitals, restaurants, schools and theatres. For each category the values of appropriate water use parameters are required. For hotels, the number of square feet is required, for schools the number of students, and so forth.

The usage of coefficients for the commercial submodel were developed in a study of commercial and institutional establishments by Wolf et al[16]. These values are stored in the library of water usage coefficients of the MAIN II system. Therefore, the user is only required to provide the appropriate value for each dependent parameter, such as a number of elementary school students or square feet of hotel space.

In the COG version of MAIN II there are eight distinct commercial categories of water users. Three of these are specified a priori and incorporated in the system and the coefficient library. For the five user-specified categories it was necessary to aggregate mean annual, maximum day and peak hour usage coefficients. For this purpose, each category was divided into its smallest components based on the SIC code or other available data. As an example, Transportation/Communication/Utilities was divided into 8 subcategories such as transportation by air, communication, and local passenger transit. The eight categories and their definitions are listed in Table 2, on the fourth page.

Predicting Public-Unaccounted Water Usage

The public-unaccounted submodel computes water which is pumped without subsequent recovery of revenue from a residential, commercial, or industrial customer. This usage is divided into the following three categories: free service, losses (probably due to leakage), and usage by airports. Computation is based on national average per-capita usage coefficients.

CHARACTERISTICS OF OPERATION

Input-Output Flowchart - The input-output flowchart and program listings for the available MAIN II program are available in Appendix A of Reference 20, MAIN II System Users Manual, Volume II.

Input Descriptions - The MAIN II input data as used in the Framework model is shown in Figure 5.

The category required, "Municipal Data", consists of the following data subgroups:

Municipal Data Subgroup	Definition	Used in this Version
OPTIONS	Run and output options	Yes
CITYDATA	Municipal identification data	Yes
METRSEWR	Metered water bill and public sewered residences	Yes
METRSEWR	Metered water bill & septic tank residences	No-assume 100% of population sewered
FLATSEPT	Flat rate water bill & public sewered residences	Yes
FLATSEPT	Flat rate water bill & septic tank residences	No
COMMPARM	Commercial/Institutional Parameters	Yes
INDPARAM	Industrial Param. (employment)	No - (included in COMMPARM instead
PUBPARAM	Public/Unaccounted parameters	Yes
PUBANAVE	Public/Un. ann. avg. water req.	No-not needed
PUBMAXDY	Public/Un. max. day water req.	No-not needed
PUBPEKHR	Public/Un. peak hr. water req.	No-not needed six using PUBPARAM

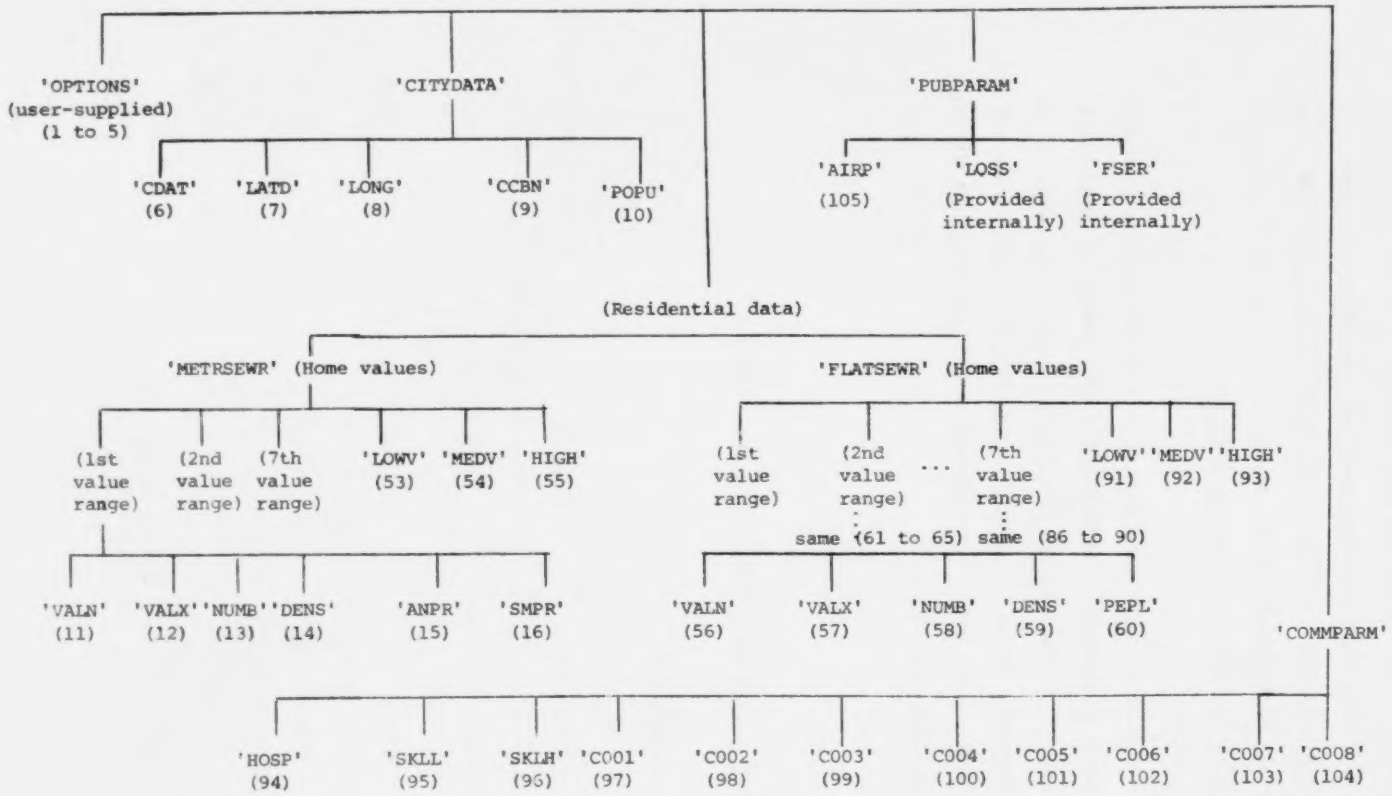
'OPTIONS'
(user-supplied)
(1 to 5)
'CITYDATA'
'CDAT'
(6)
'LATD'
(7)
'LONG'
(8)
'CCBN'
(9)
'POPU'
(10)
'PUBPARAM'
'AIRP'
(105)
'LOSS'
(Provided internally)
'FSER'
(Provided internally)
(Residential data)
'METRSEWR' (Home values)
(1st value range)
(2nd value range)
(7th value range)
'LOWV'
(53)
'MEDV'
(54)
'HIGH'
(55)
'VALN'
(11)
'VALX'
(12)
'NUMB'
(13)
'DENS'
(14)
'ANPR'
(15)
'SMPR'
(16)
'FLATSEWR' (Home values)
(1st value range)
(2nd value range)
...
(7th value range)
'LOWV'
(91)
'MEDV'
(92)
'HIGH'
(93)
same (61 to 65)
same (86 to 90)
'VALN'
(56)
'VALX'
(57)
'NUMB'
(58)
'DENS'
(59)
'PEPL'
(60)
'COMMPARM'
'HOSP'
(94)
'SKLL'
(95)
'SKLH'
(96)
'C001'
(97)
'C002'
(98)
'C003'
(99)
'C004'
(100)
'C005'
(101)
'C006'
(102)
'C007'
(103)
'C008'
(104)

FIGURE 5. MAIN II INPUT DATA - MUNICIPAL DATA

As shown in Figure 5, each subgroup requires data for a number of parameters: For example, the subgroup 'CITYDATA' requires values for each combination of planning unit, development policy and forecast year for the following five parameters: 'CDAT', 'LATD', 'LONG', 'CCBN', and 'POPU'. The number in parenthesis in the figure refers to the position of each data element in the INTERFACE matrix ZMAIN.

Realizing that such data identification names need further explanation, Table 3 has been provided. Included in this table is the name, definition, and the unit of measurement of each parameter, as well as an indication of the necessary level of detail. Of the 105 data elements required for each planning unit, 65 are considered to remain constant for all development plans and forecast years.

TABLE 3

MAIN II PARAMETERS AND VARIABLES

A. Run and Output Descriptions

Name of Parameter	Definition	Units	Parameters Required By
'MACH'	Computer ID number	N/A	N/A
'LBIN'	Fortran input device for Library	N/A	N/A
'LIBY'	Option to print for Library	N/A	N/A
'PROJ'	Auxiliary storage to do forecasting	N/A	N/A
'PNCH'	Option to punch deck of output	N/A	N/A

Parameters and Variables in MAIN II

B. Municipal Identification Data

'CITYDATA' Subgroup

Name of Parameters	Definition	Units	Parameters Required By
'CDAT'	Selected year for analysis	Year	Planning unit
'LATD'	Latitude of planning unit	Whole degrees	Planning unit
'LONG'	Longitude of planning unit	Whole degrees	Planning unit
'CCBN'	Dept. of Commerce National Composite Construction Cost Index to deflate home values to 1960 price level	Index	Metro region
'POPU'	Population	People	Planning unit

c. Residential Data

Name of Parameter	Definition	Units	Parameters Required By
'METRSEWR' Subgroup			
'NUMB'	Number of occupied housing units	# units	each value range* within planning unit
'DENS'	Housing density housing units	units/ res. acre	planning unit
'ANPR'	Marginal price of water (year round)	¢/ 1000 gal.	each water authority within planning unit
'SMPR'	Summer price of water	¢/ 1000 gal.	each water authority within planning unit
'VALN'	Lower limit of each	$	each value range
'VALX'	Upper limit of each	$	each value range
'LOWV'	Number of value ranges with median value below $7500 1960 dollars	# ranges	Planning unit Planning unit

Table 3 (continued)

Parameters and Variables in MAIN II

'MEDV'	Number of value ranges with median value of at least $7500 but less than $15,000 1960 dollars	# ranges	Planning unit
'HIGH'	Number of value ranges with median value of at least $15,000 1960 dollars	# ranges	Planning unit

'FLATSEWR' Subgroup

'NUMB'	(See METRSEWR)		
'DENS'	(See METRSEWR)		
'PEPL'	Population density	persons per housing unit	Planning unit
'VALN'			
'VALX'			
'LOWV'	(See METRSEWR)		
'MEDV'			
'HIGH'			

D. Commercial/Institutional Data

'COMMPARM' Subgroup

Name of Parameter	Definition	Units	Parameters Required By
'HOSP'	Hospitals	Beds	Planning unit
'SKLL'	School, Elementary	student	Planning unit
'SKLH'	School, High	student	Planning unit
C001	Manufacturing/Transp. Communications, utilities employment	people employed	Planning unit
C002	Retail/Wholesale Trade employment	people employed	Planning unit
C003	Finance, Insurance, Real Estate/Services employment	people employed	Planning unit
C004	Government employment	people employed	Planning unit

Table 3 (continued)

Parameters and Variables in MAIN II

C006	Not being used
C007	Not being used
C007	Not being used

E. Public/Unaccounted Data

'PUBPARAM' subgroup

Name of Parameter	Definition	Units	Parameters Required By
"AIRP'	Water required by airport to extent it is provided from municipal system	avg. # passengers /day	Planning unit (if it has airport)
'POPU'	Determined under 'CITYDATA' Subgroup		

Typical Outputs

Table 4 displays the output from a typical application of MAIN II. It summarizes the average daily water use quantities as computed from equations (1) through (5). Also included in the tables are the quantities which represent maximum daily and peak hourly use.

MODEL AVAILABILITY

The Main II model, modified as described here, may be obtained from the Metropolitan Washington Council of Governments, 1225 Connecticut Avenue, N.W., Washington, D.C. 20036.

```
              MUNICIPAL WATER REQUIREMENTS FOR THE CITY OF PLANNING UNIT 2
                    FOR THE YEAR 1976 ANALYZED BY MAIN SYSTEM

                    CURRENT RESIDENTIAL WATER REQUIREMENTS BY CATEGORY
                           METERED AND SEWERED AREAS (A)

                        NO. OF
VALUE RANGE ($)         UNITS      DOMESTIC SPRINKLING      AVG. DAY      MAX. DAY       PEAK HOUR (C)
    0. -  4999.           175.        19975.       391.        20366.        25657.         110112.
 5000. -  9999.          1107.       145709.     12185.       157894.       245790.         865390.
10000. - 14999.          4543        676998.    104918.       781916.      1338066.        4216309.
15000. - 19999.          7911.      1316054.    297575.      1613628.      2890580.        8472480.
20000. - 24999.          9211.      1692201.    498833.      2191033.      4008858.       11162374.
25000. - 34999.          6105.      1280531.    501788.      1782318.      3287690.        8670464.
35000. - 40000.          4421.      1042349.    502194.      1544542.      2831443.        7187677.
          TOTAL         33473.      6173816.   1917882.      8091696.     14628083.       40684784.
```

Explanatory Notes:

(A) Metered and Sewered Areas were assumed to be single family households -- see text.

(B) Home Value Ranges.

(C) Expressed as daily consumption. True peak hour consumption equals one twenty fourth the amount printed.

TABLE 4 EXAMPLE OF OUTPUT FROM MAIN II

MUNICIPAL WATER REQUIREMENTS FOR THE CITY OF PLANNING UNIT 2
FOR THE YEAR 1976 ANALYZED BY MAIN SYSTEM

CURRENT RESIDENTIAL WATER REQUIREMENTS BY CATEGORY
FLAT RATE AND SEWERED AREAS (A)

VALUE RANGE ($)	NO. OF UNITS	DOMESTIC	SPRINKLING	AVG. DAY	MAX. DAY	PEAK HOUR(C)
0. - 4999.	431.	53096.	0.	53096.	53096.	250962.
5000. - 7499.	1378.	192598.	0.	192598.	192598.	848848.
7500. - 9999.	3101.	467382.	0.	467382.	467382.	1978560.
10000. - 12499.	3704.	598917.	0.	598917.	598917.	2445283.
12500. - 14999.	11700.	2020088.	0.	2020088.	2020088.	7982418.
15000. - 17499.	13624.	2501674.	0.	2501674.	2501674.	9596167.
17500. - 25000.	15569.	3200707.	0.	3200707.	3200707.	11655927.
TOTAL	49508.	9034461.	0.	9034461.	9034461.	34758144.

Explanatory Notes:

(A) Flat Rate and Sewered areas were assumed to be apartments - see text.

(B) Apartment value range.

(C) Expressed as daily consumption. True peak hour consumption equals one twenty fourth of the amount printed.

TABLE 4 EXAMPLE OF OUTPUT FROM MAIN II

(Continued)

```
            MUNICIPAL WATER REQUIREMENTS FOR THE CITY OF PLANNING UNIT 2
                    FOR THE YEAR 1976 ANALYZED BY MAIN SYSTEM

            CURRENT RESIDENTIAL WATER REQUIREMENTS IN GALLONS PER DAY

            Average              Maximum              Peak
            Daily                Daily                Hourly (A)
            17126144.            23662528.            75442928.

                    REQUIREMENTS BY TYPE - DAILY AVERAGE

                                                              Gallons Per Day
Type                              No. of Units    Domestic      Sprinkling        Total
(Single-Family) Metered and
  Sewered Areas                      33473.       6173816.      1917882.        8091696.
(Apartment) Flat Rate and
  Sewered Areas                      49508.       9034461.            0.        9034461.
                       TOTAL         82981.      15208277.      1917882.       17126144.


                    Summer Evapotranspiration % Inches<#          16.00
                    Summer Precipitation % Inches< #               6.75
                    Max. Day Evapotranspiration % Inches< #        0.29

Explanatory Notes:
(A)  Expressed as daily consumption.
```

TABLE 4 EXAMPLE OF OUTPUT FROM MAIN II

(Continued)

MUNICIPAL WATER REQUIREMENTS FOR THE CITY OF PLANNING UNIT 2
FOR THE YEAR 1976 ANALYZED BY MAIN SYSTEM

TOTAL COMMERCIAL$^{(A)}$ REQUIREMENTS IN GALLONS PER DAY

Average Daily	Maximum Daily	Peak Hourly
7846069.	12844744.	33959152.

WATER REQUIREMENTS BY TYPE OF COMMERCIAL ESTABLISHMENT

Type	Units	No. of Units	Average Daily	Maximum Daily	Peak Hourly
			% Gallons Per Day		
Hospitals	Bed	497.	171962.	273847.	453264.
School, Elem.	Student	38102.	204989.	368827.	1870807.
School, High	Student	26036.	172619.	510305.	3150356.
Manu/TCU	Employees	14817.	2874942.	2990663.	3496219.
Trade	Employees	11315.	819432.	2204953.	5718260.
Fire/Serv.	Employees	29737.	1074397.	1796709.	5082945.
Government	Employees	87990.	2498915.	4645870.	14025605.

Explanatory Notes:

(A) Commercial included small amount of industrial, see text.

TABLE 4 EXAMPLE OF OUTPUT FROM MAIN II

(continued)

```
        MUNICIPAL WATER REQUIREMENTS FOR THE CITY OF PLANNING UNIT 2
                FOR THE YEAR 1976 ANALYZED BY MAIN SYSTEM


          TOTAL PUBLIC-UNACCOUNTED REQUIREMENTS IN GALLONS PER DAY

          Average              Maximum               Peak
          Daily                Daily                 Hourly(A)

          4261963.             4261963.              4261963.


     REQUIREMENTS BY TYPE OF PUBLIC-UNACCOUNTED USAGE IN GALLONS PER DAY

                        Average           Maximum          Peak
     Type               Daily             Daily            Hourly

     Distrib. Losses    3159366.          3159366.         3159366.
     Free Services      1102597.          1102597.         1102597.


     Explanatory Notes:
     (A)  Expressed as daily consumption.
```

TABLE 4 EXAMPLE OF OUTPUT FROM MAIN II

(continued)

```
SUMMARY OF MUNICIPAL WATER REQUIREMENTS FOR CITY OF PLANNING UNIT 2


                ESTIMATED WATER REQUIREMENTS FOR YEAR 1976
                   % ALL VALUES IN GALLONS PER DAY

                      Average            Maximum           Peak
                      Daily              Daily             Hourly(A)
Municipal             29234160.          35770544.         87550944.
Residential           17126144.          23662528.         75442928.
Commercial             7846069.          12844744.         33959152.
Industrial                   0.                 0.                0.
Public and Unacc.      4261963.           4261963.          4261963.


Explanatory Note:
(A)  Expressed as daily consumption
```

TABLE 4 **EXAMPLE OF OUTPUT FROM MAIN II**

(continued)

FIXSEWER

PURPOSE

The purpose of the FIXSEWER program is to adapt the water demand data output from the MAIN II program to the input specifications for the SEWAGE and MUNWATRE programs. The MAIN II program generates a data set for water demand by planning unit. A set of records for each planning unit contains flat rate (apartment,) metered (single family,) commercial, and public and unaccounted water demands. Each of these sets contain the average, maximum, and peak hour demand and, for residential data, demand by each of seven homes value ranges.

If a planning unit has no water demand data for a major category the MAIN II program will not write that portion of the set. The SEWAGE program must have a complete set of records for each planning unit. The FIXSEWER program is needed to verify the order of the data fields from MAIN II and insert dummy data for any fields that are missing. When FIXSEWER encounters missing fields, it prints an output message indicating which field is missing, inserts the key word for that field, a blank for the data value, and flags the record with an identifier.

CHARACTERISTICS OF OPERATION

Language:	ANSI COBOL
Region:	Program will execute in a 32K region

PROGRAM DESCRIPTION

FIXSEWER's first program command opens all input and output files and initializes work areas. The control card file is read and the program continues. If an end of file is detected an error message is displayed on the printer and the run is terminated.

The first record of the input file, which is the MAIN II output file, is read and the identity of each subset examined. The first subset, the flat rate service demand data, is identified by 'FLTSEWUS'. If the subset read is tagged with this identifier the program checks for identifying subset detail and inserts blank data values into the subset before writing it into the FIXSEWER output file. If the record has been modified by the program a flag 'CG' is placed in columns 75 and 76 of the record. If the subset identifier read by the program is not 'FLTSEWUS', an error message is displayed and a dummy subset of 'FLTSEWUS' records is created and written into the FIXSEWER output file to complete it.

The user supplied input/output print option control card is checked after each subset of the MAIN II dataset is read in and after each subset is written to the FIXSEWER output dataset to determine if the records should be printed.

This basic operation of checking for the proper subset identifier, checking for missing subset detail, inserting blank data values, creating dummy subset records when the subset identifier is missing, and checking the control card for print options is also performed on all subsets. The subsets must be in the order shown.

The process is repeated for each planning unit set until an end of file signal is reached on the MAIN II file. The program then closes all input and output files and displays count of total input records and total output records.

SAMPLE SETUP - See input-output flow chart

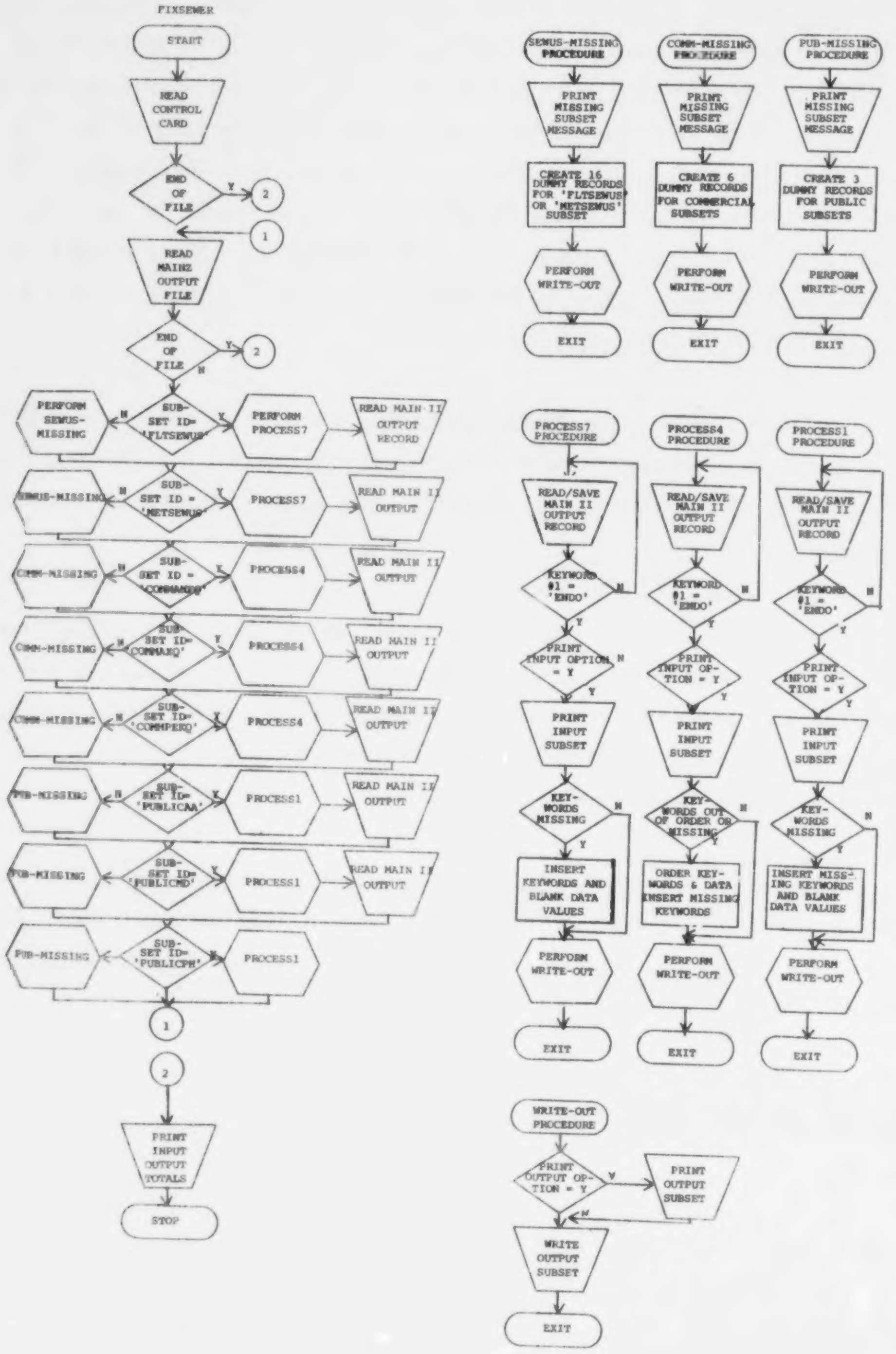
FIXSEWER
START
READ CONTROL CARD
END OF FILE
Y
N
2
1
READ MAIN2 OUTPUT FILE
PERFORM SEWUS-MISSING
SUB-SET ID= 'FLTSEWUS'
PERFORM PROCESS7
READ MAIN II OUTPUT RECORD
SEWUS-MISSING
SUB-SET ID = 'METSEWUS'
PROCESS7
READ MAIN II OUTPUT
COMM-MISSING
SUB-SET ID= 'COMMANDQ'
PROCESS4
SUB-SET ID= 'COMMAEQ'
SUB-SET ID= 'COMMPERQ'
PUB-MISSING
SUB-SET ID= 'PUBLICAA'
PROCESS1
SUB-SET ID= 'PUBLICMD'
SUB-SET ID= 'PUBLICPH'
PRINT INPUT OUTPUT TOTALS
STOP
SEWUS-MISSING PROCEDURE
COMM-MISSING PROCEDURE
PUB-MISSING PROCEDURE
PRINT MISSING SUBSET MESSAGE
CREATE 16 DUMMY RECORDS FOR 'FLTSEWUS' OR 'METSEWUS' SUBSET
CREATE 6 DUMMY RECORDS FOR COMMERCIAL SUBSETS
CREATE 3 DUMMY RECORDS FOR PUBLIC SUBSETS
PERFORM WRITE-OUT
EXIT
PROCESS7 PROCEDURE
PROCESS4 PROCEDURE
PROCESS1 PROCEDURE
READ/SAVE MAIN II OUTPUT RECORD
KEYWORD #1 = 'ENDO'
PRINT INPUT OPTION = Y
PRINT INPUT SUBSET
KEY-WORDS MISSING
KEY-WORDS OUT OF ORDER OR MISSING
INSERT KEYWORDS AND BLANK DATA VALUES
ORDER KEY-WORDS & DATA INSERT MISSING KEYWORDS
INSERT MISSING KEYWORDS AND BLANK DATA VALUES
WRITE-OUT PROCEDURE
PRINT OUTPUT OPTION = Y
PRINT OUTPUT SUBSET
WRITE OUTPUT SUBSET

FIGURE 6. FIXSEWER PROGRAM FUNCTION FLOWCHART

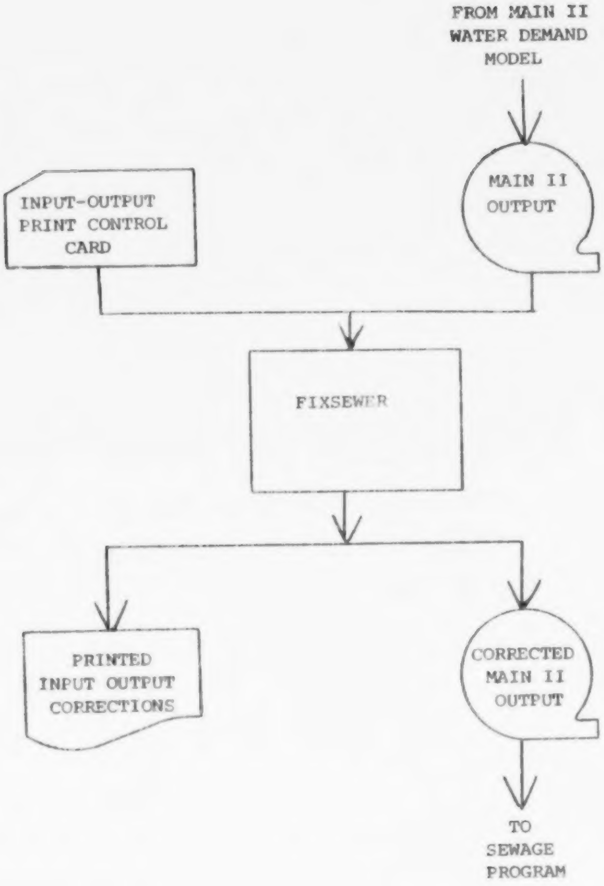
FROM MAIN II
WATER DEMAND
MODEL
MAIN II
OUTPUT
INPUT-OUTPUT
PRINT CONTROL
CARD
FIXSEWER
PRINTED
INPUT OUTPUT
CORRECTIONS
CORRECTED
MAIN II
OUTPUT
TO
SEWAGE
PROGRAM

FIGURE 7. INPUT-OUTPUT FLOWCHART FOR FIXSEWER

DATA SPECIFICATION

Input Description

Input to FIXSEWER is in the form of two files; a computer generated data file and user control card.

The data file is the output from the MAIN II program and is assigned in this program to DDNAME 'SYSO12'. This file contains the water demand data (see below) for each planning unit.

A user-supplied control card must be present for the program to execute. This card gives the user the option of printing the input and/or output data from the program. The DDNAME of the Control Card File is 'SYSO11'.

The format of the card is:

Col. 1 = 'Y'	This indicates the input data is to be printed. If this information is not needed, leave this field blank.
Col. 2 = 'Y'	This indicates the output data is to be printed. If this information is not needed, leave this field blank.
Col. 3-80 BLANKS	

The MAIN II output data file consists of a set of water demand data for each planning unit. A set consists of eight subsets. The subsets are:

Subset Identifier		Data
'FLTSEWUS'	containing water use by	flat rate apartments
'METSEWUS'	containing water use by	Metered Single Family
'COMMAVEQ'	containing water use by	Commercial (Average Daily)
'COMMXQ'	containing water use by	Commercial (Maximum Daily)
'COMMPEKQ	containing water use by	Commercial (Peak Hour)
'PUBLICAA'	containing water use by	Public and Unaccounted (Average Daily)
'PUBLICMD'	containing water use by	Public and Unaccounted (Maximum Daily)
'PUBLICPH'	containing water use by	Public and Unaccounted (Peak Hour)

The subsets 'FLTSEWUS' and 'METSEWUS' contain component records identified by:

QDOM	This component record contains domestic usage in gallons
QSAV	This component record contains sprinkling usage in gallons
QSMX	This component record contains maximum daily usage in gallons
QPEK	This component record contains peak hour usage in gallons
NUMB	This component record contains number of households

The five keywords above are repeated for each of the seven home value ranges from the MAIN II model.

Subsets 'COMMAVEQ', 'COMMAXQ' and 'COMPEKQ' contain component records identifiably:

HOSP	This component record contains hospital usage in gallons
SKLL	This component record contains elementary school usage in gallons
SKLH	This component record contains high school usage in gallons
C001-C008	This component record contains industrial usage in gallons

Subsets 'PUBLICAA', 'PUBLICMD', and 'PUBLICPH' contain component records identified by:

LOSS	This component record contains distributed losses in gallons.
FREE	This component record contains free service usage in gallons
AIRP	This component record contains airport usage in gallons

The last record of each subset contains only the component 'ENDD'.

SUBSET IDENTIFIER RECORD FORMAT

Column	Data
1-1	Blank
2-9	Subset identifier
10-10	Blank
11-14	Data Year
15-72	Blank
73-74	2 Character Subset Identifier
75-78	Data Year
79-80	Subset Card Sequence Number

SUBSET RECORD FORMAT

Column	Data
1-1	Blank
2-5	Keyword #1
6-18	Value #1
24-27	Keyword #2
28-40	Value #3
46-49	Keyword #3
50-62	Value #3
63-72	Blank
73-80	Same as subset identifier record

Output Description

The FIXSEWER program writes one output file that contains the corrected MAIN II output water demand data. The format and organization of the data is the same as the MAIN II output. (See Table 5). The DDNAME for this file is 'SYS008'. Descriptive messages are printed whenever a subset or part of a subset is missing and has to be replaced by the program. The DDNAME for the print file is 'SYS014'.

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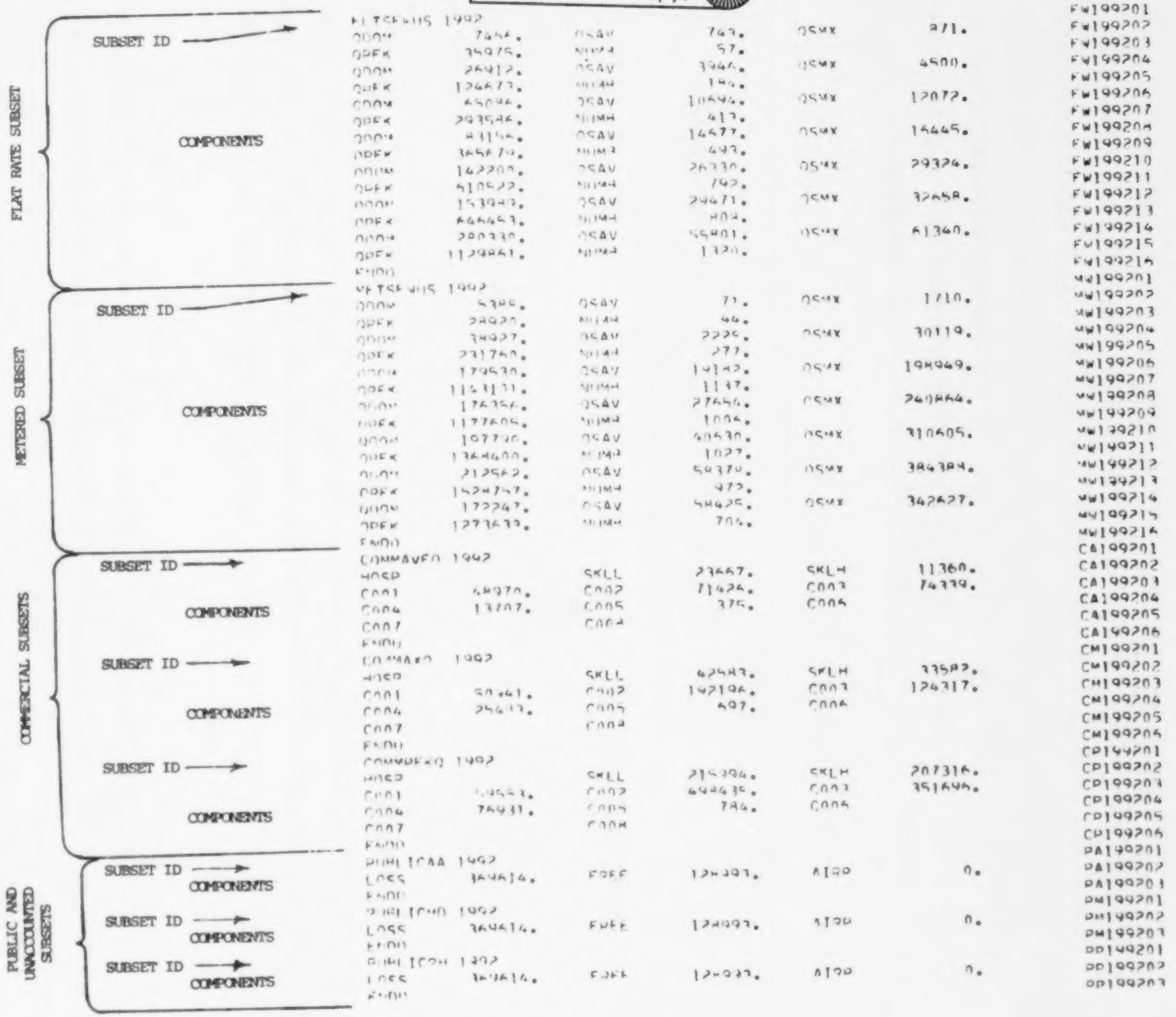


```
FLTSEWUS 1992                                                           FW199201
000M      7456.    0SAV       743.    0SMX       871.                   FW199202
0PEK     35975.    NUMH        57.                                      FW199203
000M     26912.    0SAV      3946.    0SMX      4500.                   FW199204
0PEK    124673.    NUMH       144.                                      FW199205
000M     65096.    0SAV     10694.    0SMX     12072.                   FW199206
0PEK    293586.    NUMH       417.                                      FW199207
000M     83156.    0SAV     14577.    0SMX     16445.                   FW199208
0PEK    365670.    NUMH       493.                                      FW199209
000M    142200.    0SAV     26330.    0SMX     29324.                   FW199210
0PEK    510522.    NUMH       792.                                      FW199211
000M    153943.    0SAV     29471.    0SMX     32658.                   FW199212
0PEK    666453.    NUMH       808.                                      FW199213
000M    280330.    0SAV     55801.    0SMX     61340.                   FW199214
0PEK   1129861.    NUMH      1320.                                      FW199215
ENDD                                                                    FW199216
METSEWUS 1992                                                           MW199201
000M      5385.    0SAV        71.    0SMX      1710.                   MW199202
0PEK     28920.    NUMH        44.                                      MW199203
000M     38927.    0SAV      2225.    0SMX     30119.                   MW199204
0PEK    231760.    NUMH       277.                                      MW199205
000M    179530.    0SAV     19182.    0SMX    198949.                   MW199206
0PEK   1143131.    NUMH      1137.                                      MW199207
000M    176356.    0SAV     27654.    0SMX    240864.                   MW199208
0PEK   1177605.    NUMH      1006.                                      MW199209
000M    197790.    0SAV     40530.    0SMX    310605.                   MW199210
0PEK   1364600.    NUMH      1027.                                      MW199211
000M    212562.    0SAV     59370.    0SMX    384384.                   MW199212
0PEK   1528757.    NUMH       972.                                      MW199213
000M    172267.    0SAV     58425.    0SMX    342627.                   MW199214
0PEK   1273633.    NUMH       706.                                      MW199215
ENDD                                                                    MW199216
COMMAVED 1992                                                           CA199201
HOSP               SKLL     23667.    SKLH     11360.                   CA199202
C001     68970.    C002     71426.    C003     74339.                   CA199203
C004     13707.    C005       375.    C006                              CA199204
C007               C008                                                 CA199205
ENDD                                                                    CA199206
COMMAXED 1992                                                           CM199201
HOSP               SKLL     42583.    SKLH     33582.                   CM199202
C001     50441.    C002    142196.    C003    124317.                   CM199203
C004     25633.    C005       497.    C006                              CM199204
C007               C008                                                 CM199205
ENDD                                                                    CM199206
COMMPEKD 1992                                                           CP199201
HOSP               SKLL    215394.    SKLH    207316.                   CP199202
C001     59553.    C002    694435.    C003    351696.                   CP199203
C004     76931.    C005       784.    C006                              CP199204
C007               C008                                                 CP199205
ENDD                                                                    CP199206
PUBLICAA 1992                                                           PA199201
LOSS    369614.    FREE    128393.    AIRP         0.                   PA199202
ENDD                                                                    PA199203
PUBLICMD 1992                                                           PM199201
LOSS    369614.    FREE    128393.    AIRP         0.                   PM199202
ENDD                                                                    PM199203
PUBLICPK 1992                                                           PP199201
LOSS    369614.    FREE    128393.    AIRP         0.                   PP199202
ENDD                                                                    PP199203
```

FLAT RATE SUBSET
SUBSET ID
COMPONENTS
METERED SUBSET
SUBSET ID
COMPONENTS
COMMERCIAL SUBSETS
SUBSET ID
COMPONENTS
SUBSET ID
COMPONENTS
SUBSET ID
COMPONENTS
PUBLIC AND UNACCOUNTED SUBSETS
SUBSET ID
COMPONENTS
SUBSET ID
COMPONENTS
SUBSET ID
COMPONENTS

TABLE 5. FORMAT OF FIXSEWER OUTPUT

Water Demands By Planning Unit With Subset and Component Breakdowns

MUNWATRE

PURPOSE

The purpose of the MUNWATRE program is to summarize the output of the FIXSEWER program. It is printed as average daily, maximum daily or peak hour municipal water requirement reports. Each report presents the water demands by planning units and water usage categories. This program was written to provide a quick summary of the water demand projections for the specific model run. If the Framework Model were used only as a water demand projecting tool, computation would stop with this summary.

CHARACTERISTICS OF OPERATIONS

Language:	ANSI Cobol
Region:	Program will execute in a 38K region plus the Buffer Size. The sample run used 80K.

PROGRAM DESCRIPTION

The MUNWATRE program reads the water demand file, which is the output from the FIXSEWER program, and examines the SUBSET ID RECORD. This ID, when matched to one of a set of literals established in the program, initiates the proper branch instruction for the accumulation of the subset data. The subset records are then read in and the data values are accumulated in one of three arrays; average daily, maximum daily, peak hour. This process is repeated until an end of file signal is read on the input file. The program then prints the number of planning units and total records input and processed.

The control card file is then read and checked for a valid keyword. If any keyword is mispelled, the program will terminate with an explanatory message. The absence of any of the keywords will not cause the program to stop, but the descriptive information in the report title or column headings will be missing. The report type card then directs the program to print the data from one of the three arrays. After the first report is printed the control card file is read again for further descriptive information and program type cards. This process is repeated until the end of file is reached, at which time the program comes to a normal end of job.

Sample Setup. See input-output flowchart

DATA SPECIFICATION

Input Description

Input to MUNWATRE is in the form of two files; the FIXSEWER output file and the user control card file.

The input file is in the MAIN II water demand output file as corrected by the FIXSEWER program. The MUNWATRE program will process an input file with up to 100 planning unit sets of data. This input file is assigned to DDNAME 'WATERI'.

The user control cards supply the descriptive information needed for the output print lines and also directs the program to print the required reports. A minimum of four control cards are needed to produce one report. If more than one report is to be printed, two control cards, a Title card and Report Type card, must be added for each additional report with the Study Year and Geographic Units Cards being optional. There are no default values associated with the control card information. The Title card, Study Year card and the Geographic Units card must precede the Report Type card for first report. The control card file is assigned to DDNAME 'CARDI'.

The control cards for the program operation must be in the following order:

CARD #1

Type:	Title Card		
Number:	One for each report		
Purpose:	Supplies report title for printout		
Format:	Col.	1-5	'TYPE =" keyword must becoded

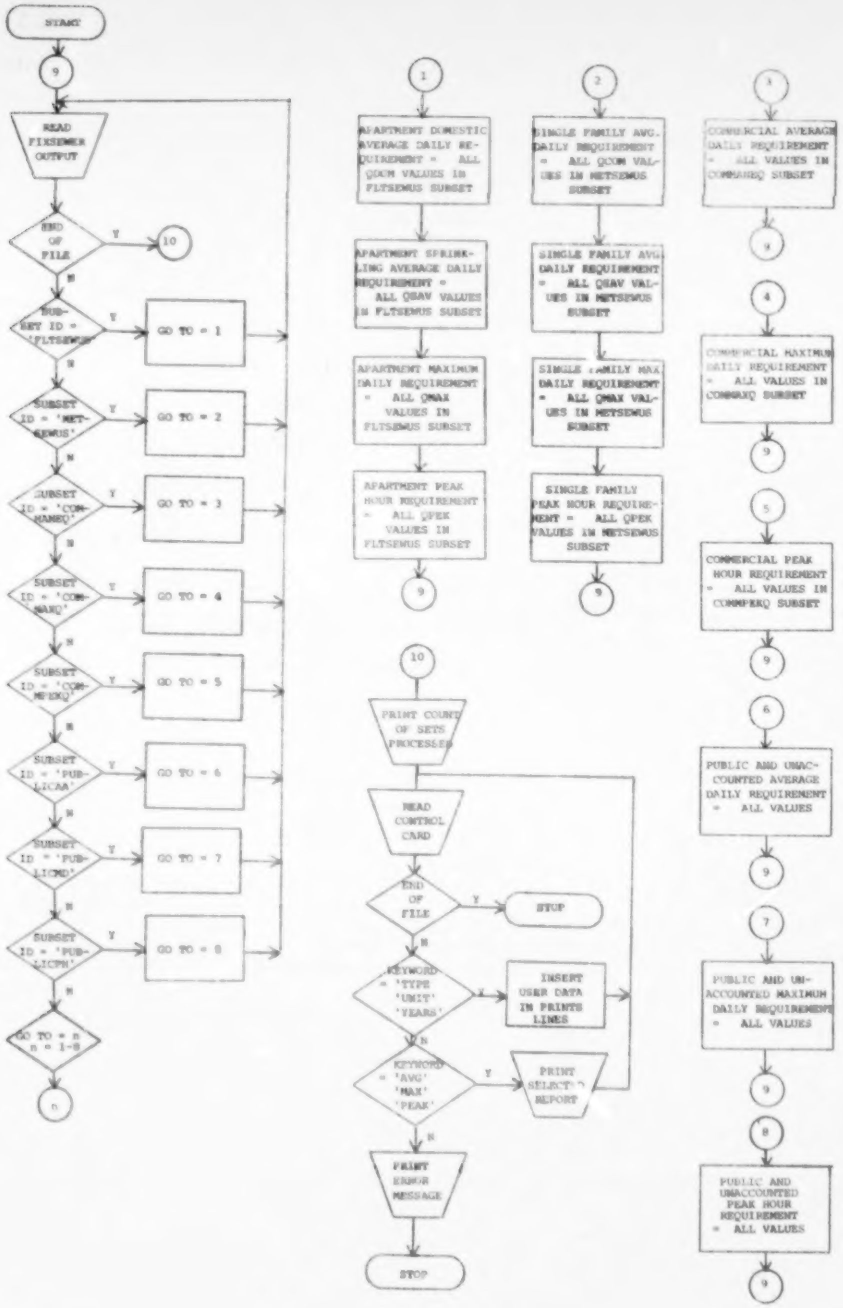
6-8	13 character description of report i.e., 'AVERAGE DAILY'
19-80	Blank or user comments

CARD #2

Type:	Report Type		
Number:	One for each report		
Purpose:	Directs program to print one of the three summary reports on water requirements		
Format:	Col.	1-4	'AVG' Print Average Daily water requirements report
		5-39	'MAX' Print Maximum Daily water requirements report 'PEAK' Print Peak Hour water requirements report
		5-80	Blank or user comments

Output Descriptions

The MUNWATRE program prints an average daily, maximum daily and/or peak hour water requirements report. Each report contains the water demand by planning units and water usage categories.



START
9
READ FIXSEWER OUTPUT
END OF FILE
Y
10
N
SUB-SET ID = 'FLTSEWUS'
Y
GO TO = 1
N
SUBSET ID = 'MET-SEWUS'
Y
GO TO = 2
N
SUBSET ID = 'COM-MANEQ'
Y
GO TO = 3
N
SUBSET ID = 'COM-MAXQ'
Y
GO TO = 4
N
SUBSET ID = 'COM-MPEKQ'
Y
GO TO = 5
N
SUBSET ID = 'PUB-LICAA'
Y
GO TO = 6
N
SUBSET ID = 'PUB-LICMD'
Y
GO TO = 7
N
SUBSET ID = 'PUB-LICPH'
Y
GO TO = 8
N
GO TO = n n = 1-8
n
1
APARTMENT DOMESTIC AVERAGE DAILY REQUIREMENT = ALL QCOM VALUES IN FLTSEWUS SUBSET
APARTMENT SPRINKLING AVERAGE DAILY REQUIREMENT = ALL QSAV VALUES IN FLTSEWUS SUBSET
APARTMENT MAXIMUM DAILY REQUIREMENT = ALL QMAX VALUES IN FLTSEWUS SUBSET
APARTMENT PEAK HOUR REQUIREMENT = ALL QPEK VALUES IN FLTSEWUS SUBSET
9
2
SINGLE FAMILY AVG. DAILY REQUIREMENT = ALL QCOM VALUES IN METSEWUS SUBSET
SINGLE FAMILY AVG. DAILY REQUIREMENT = ALL QSAV VALUES IN METSEWUS SUBSET
SINGLE FAMILY MAX DAILY REQUIREMENT = ALL QMAX VALUES IN METSEWUS SUBSET
SINGLE FAMILY PEAK HOUR REQUIREMENT = ALL QPEK VALUES IN METSEWUS SUBSET
9
3
COMMERCIAL AVERAGE DAILY REQUIREMENT = ALL VALUES IN COMMANEQ SUBSET
9
4
COMMERCIAL MAXIMUM DAILY REQUIREMENT = ALL VALUES IN COMMAXQ SUBSET
9
5
COMMERCIAL PEAK HOUR REQUIREMENT = ALL VALUES IN COMMPEKQ SUBSET
9
6
PUBLIC AND UNACCOUNTED AVERAGE DAILY REQUIREMENT = ALL VALUES
9
7
PUBLIC AND UNACCOUNTED MAXIMUM DAILY REQUIREMENT = ALL VALUES
9
8
PUBLIC AND UNACCOUNTED PEAK HOUR REQUIREMENT = ALL VALUES
9
10
PRINT COUNT OF SETS PROCESSED
READ CONTROL CARD
END OF FILE
Y
STOP
N
KEYWORD = 'TYPE' 'UNIT' 'YEARS'
Y
INSERT USER DATA IN PRINTS LINES
N
KEYWORD = 'AVG' 'MAX' 'PEAK'
Y
PRINT SELECTED REPORT
N
PRINT ERROR MESSAGE
STOP

FIGURE 8. PROGRAM FUNCTION FLOWCHART FOR MUNWATRE

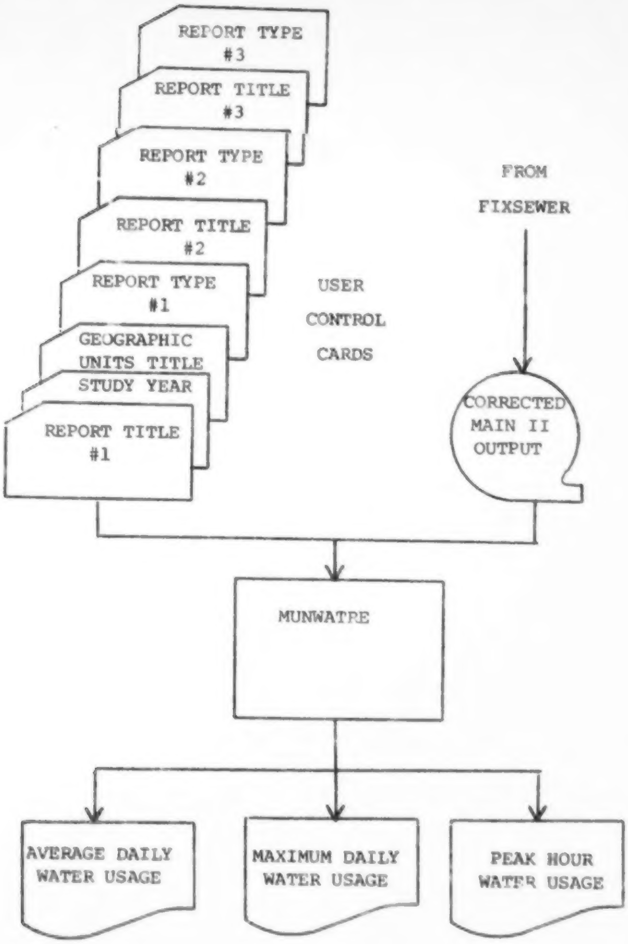

REPORT TYPE #3
REPORT TITLE #3
REPORT TYPE #2
REPORT TITLE #2
REPORT TYPE #1
GEOGRAPHIC UNITS TITLE
STUDY YEAR
REPORT TITLE #1
USER CONTROL CARDS
FROM FIXSEWER
CORRECTED MAIN II OUTPUT
MUNWATRE
AVERAGE DAILY WATER USAGE
MAXIMUM DAILY WATER USAGE
PEAK HOUR WATER USAGE

FIGURE 9. INPUT-OUTPUT FLOWCHART FOR MUNWATRE

TABLE 6. SUMMARY OF ESTIMATED AVERAGE DAILY MUNICIPAL WATER REQUIREMENTS FOR METROPOLITAN WASHINGTON FOR THE YEAR 1992 IN GALLONS PER DAY

PLANNING UNIT	RESIDENTIAL				COMMERCIAL & INDUSTRIAL	PUBLIC & UNACCOUNTED	TOTAL
	SINGLE-FAMILY HOUSEHOLDS		APARTMENTS				
	DOMESTIC	SPRINKLING	DOMESTIC	SPRINKLING			
1	4356817	1225298	12681153	2251144	66163622	5055394	91733428
2	16463076	4488569	13781156	2625892	16521933	7339756	61220382
3	4381677	889041	9357429	1563795	4066440	4256157	24514539
4	956722	298054	4110561	804161	9636532	1386776	17192806
5	4859738	1428326	6172267	1153121	3312307	3250471	20176230
6	3886571	1072942	6527158	1190989	3992228	3116138	19786026
7	4212008	1635101	4281760	811744	2534335	2332376	15807324
8	1467990	566191	1899389	352066	714225	962197	5962058
9	3084015	1165977	2642190	499038	3843552	1561571	12796343
10	2093336	880988	2508796	448113	817348	1390819	8139400
11	6115171	1619189	4356352	784351	3956922	3110783	19942768
12	2229087	841398	877112	167835	418642	801356	5335430
13	1140767	364634	1062724	142596	1383518	945980	5040219
14	3571448	1095965	2641285	462517	1107632	1926509	10805356
15	3478179	807556	2793188	507445	1352786	1832351	10771505
16	3097825	763235	1944925	358701	1556273	1425309	9146268
17	2727720	471155	1683002	299249	821007	1332364	7334497
18	810571	254063	284436	54853	1178757	284248	2866928
19	1659102	289097	1346075	231931	1520679	1051732	6098616
20	2066139	234749	1305185	225048	1106885	1194427	6132433
21	1496740	247041	1130253	195729	390946	889622	4350331
22	844490	159667	489559	92027	224526	384164	2194433
23	4285064	1375071	2603629	453810	1287073	2312153	12316800
24	3585524	641602	2292818	395668	1046818	1988256	9950686
25	2409851	445614	1117460	182739	1202926	1324057	6682647
26	4800203	3210893	2288620	477520	2425931	1560220	14763387
27	1803131	390937	1015209	202466	263526	695345	4370614
28	2716840	640429	2447821	438246	2372064	1595697	10211097
29	2767664	1570020	2298965	461690	1441694	1261653	9801695
30	2142840	1377059	2120934	401666	1559889	1190512	8792900

TABLE 6 (continued). SUMMARY OF ESTIMATED AVERAGE DAILY MUNICIPAL WATER REQUIREMENTS FOR METROPOLITAN WASHINGTON FOR THE YEAR 1992 IN GALLONS PER DAY

PLANNING UNIT	RESIDENTIAL				COMMERCIAL & INDUSTRIAL	PUBLIC & UNACCOUNTED	TOTAL
	SINGLE-FAMILY HOUSEHOLDS		APARTMENTS				
	DOMESTIC	SPRINKLING	DOMESTIC	SPRINKLING			
31	3233245	780387	3185263	560526	911097	2026408	10696926
32	4432308	1014952	5086556	891873	2728961	3020937	17175587
33	2124221	414546	1466278	262595	546895	1100310	5914845
34	2455577	2577940	3767204	759018	2480593	1601706	13642038
35	4917007	1710909	3131183	597842	1107094	2198352	13662387
36	2733981	628373	2265045	416526	2067271	1478460	9589656
37	4833532	2974461	4767501	843054	3126143	3037225	19581916
38	2863925	926224	2487711	440568	4747627	1683711	13149766
39	3870734	1764310	5487138	953914	4225585	3025311	19326992
40	2178578	678225	1722980	289058	1159976	1330781	7359598
41	1783398	603040	2416217	421464	1001554	1349468	7575141
42	3388571	1557628	4154231	727313	1782467	2418092	14028302
43	982800	206568	759139	141662	243844	498607	2832620
44	1651511	410305	2626112	453819	1194881	1372924	7709552
45	3078472	842865	2611300	452153	859002	1846211	9690003
46	455718	137605	651531	105029	913222	390448	2653553
47	1471004	430268	1730507	299594	448425	1031698	5411496
48	4519103	1024616	4737840	828883	4876175	2963213	18949830
49	204973	37409	425643	67756	330728	223675	1290184
TOTAL	150986778	49231417	154335019	27879983	173458249	90722787	646614233

SEWAGE

PURPOSE

The sewage program is used to generate a file of average daily and maximum daily sewage flows from the water requirements data estimated by MAIN II. Either infiltrated or uninfiltrated flows can be calculated depending on the program options selected by the user. The flows are needed in order to project the hydraulic loads imposed on a treatment plant by the sewage from each planning unit. In addition, the flows are multiplied by user-specified pollutant coefficients (in mg/l) to produce estimates of total sewage pollutant loads for biochemical oxygen demand (BOD), nitrogen and phosphorus.

CHARACTERISTICS OF OPERATION

Language: IBM Fortran IV (G Level)

Region: Region size of least 150K, one 132 character/line printer, one disk or four tape units.

PROGRAM DESCRIPTION

The sewage program produces a file of sewage flows and pollutant loads for each planning unit. The program processes four input files. The corrected MAIN II water requirements file (the FIXSEWER output file), the constant pollution coefficients file (a user created file containing expected concentrations in mg/l of each pollutant by planning unit), the user control card file (card file coded by user to supply information to the program) and the optional infiltration quantities for each planning unit manually derived from the developed land use forecast by the community development component. The program writes two output files, the sewage flow and loads file and a print file. The print file contains lists of the input data and printed report of the calculated flows and loads. The sewage flow and loads file is used in the TREATMENT program where it is identified by the name "wastewater".

The first operation performed by the program is to process the user control card file. The first card input, which must be the Title Card, is printed and saved for the future print operations. The second user control card input must be the Planning Units Card. This card contains the number of planning units on the MAIN II water requirements file. The third card processed should be the Option Card. The Option Card contains the FORTRAN unit assignments for the input and output files and provides the user with the option to print the corrected MAIN II water requirements data.

The program then reads into an array the FIXSEWER data and prints that data, if the user selected the print option.

The constant pollution coefficients file, created by the user, is read by the program and entered into an array. The user must create a record containing coefficients for each planning unit as there are no internal program default values assumed for the pollution coefficients.

After all the records on the pollution coefficients file have been processed, the user control card file is read and checked for pollution coefficient updates. This User Control Card enables the user to specify pollution coefficients to override those existing in the original file. Coefficient updates, if present are inserted in the pollution coefficients array. The User Control Card file is read until all the coefficients updates have been input. The end of the updates is signaled by a 999 card.

The program checks for the presence of the optional infiltration factors file by examining the Option Card for a FORTRAN unit number. A zero FORTRAN unit number shows the file was not supplied. If the unit number is other than zero, then the infiltration factors are read from that FORTRAN unit number into an array to be used in the calculation of the infiltration component of the sewage flows. In this optional file there must be one infiltration factor for each unit. For each planning unit with no specified infiltration factor a default value of zero is used.

The sewage flows for the average daily and maximum daily requirements are computed by the following general equation:

$$\text{Flow}_i = \left[\text{Demand}_i \left[.000001 \text{ Adjustment}_i\right]\right] + \text{Infiltration}_i$$

Where Flow_i is the sewage flow for planning unit i

Demand_i is the sum of the commercial and domestic requirements for planning unit i

Adjustment_i is the calibration factor for planning unit i

.000001 is a factor to change the unit of measure to millions of gallons per day

Infiltration is the amount in millions of gallons/day infiltrating the sewer system..

In the above equation when computing average flow, Demand_i is defined as the sum of the average domestic water requirements and the average commercial requirements. When maximum flows are computed Demand_i is equal to the sum of the average residential domestic requirements and maximum commercial requirements.

The sewage loads are computed by the following general equation:

$$\text{Load}_{ij} = \left\{\left[\text{Dom}_i \ {*}\text{COEFF1}_{ij}\right] + \left[\text{Comm}_i \ {*} \ \text{COEFF2}_{ij}\right]\right\} {*} \left\{8.34\left[.000001\right]\right\}$$

Where:

Load_{ij} + the load in pounds per day of pollutant j for planning unit i

Dom_i = domestic residential water requirements for planning unit i in gallons per day

COEFF1_{ij} = expected domestic concentration of pollutant j in mg/l for planning unit i

$Comm_i$ = commercial water requirements for planning unit i in gallons per day

$COEFF2_{ij}$ = expected commercial concentration of pollutant j in mg/l for planning unit i

Constants change units of measure to pounds per day.

In the above equation, the $domestic_i$ variable is always equal to the average domestic residential water demand. $Commercial_i$ is equal to the average commercial water demand when computing average loads and is equal to the maximum water demand when computing maximum pollutant loads.

The flows and loads are computed for all planning units and stored in an array from which they are retrieved for the printed report and the output flows and loads file.

The printed reports include a table of the summarized domestic residential and commercial water requirements and infiltration contribution to sewage flow, a table of adjustment factors and pollution coefficients, and a table displaying the average flows and pollution loads for each planning unit.

After the last report is printed the program writes the output file containing the average and maximum flows and loads and prints an end of job message.

This output file will then be one of the two input files to the waste treatment component.

SAMPLE SETUP

See the input - output flowchart for SEWAGE

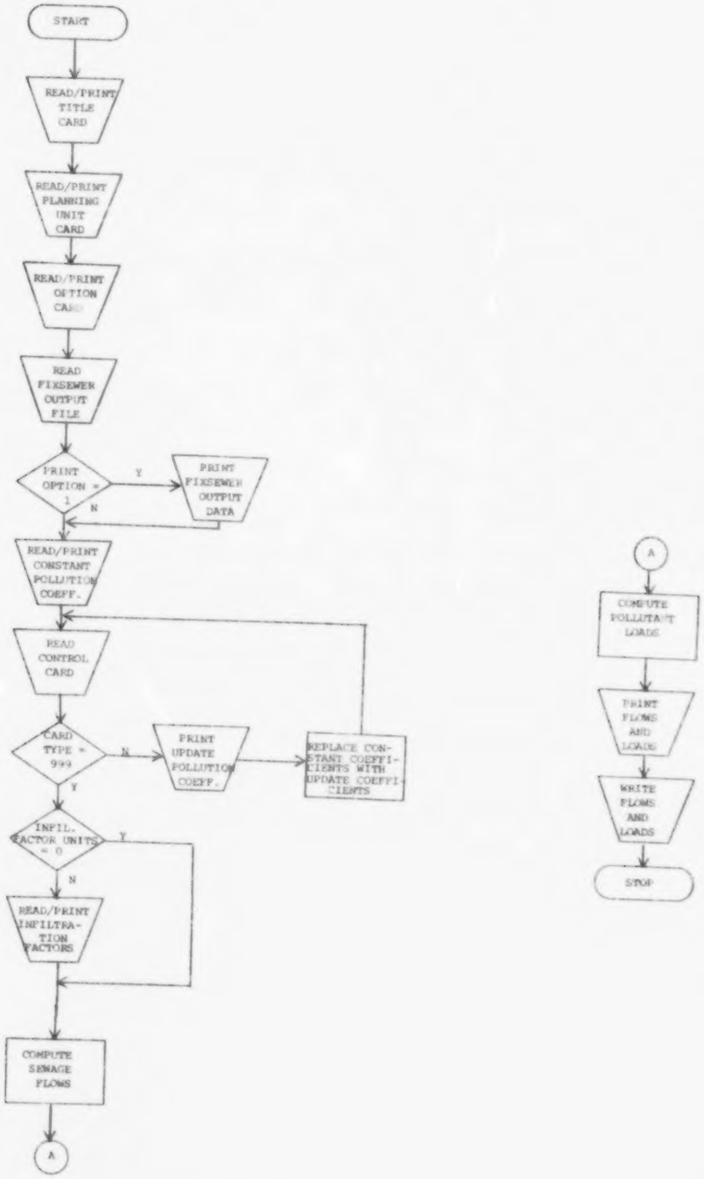

START
READ/PRINT TITLE CARD
READ/PRINT PLANNING UNIT CARD
READ/PRINT OPTION CARD
READ FIXSEWER OUTPUT FILE
PRINT OPTION = 1
Y
N
PRINT FIXSEWER OUTPUT DATA
READ/PRINT CONSTANT POLLUTION COEFF.
READ CONTROL CARD
CARD TYPE = 999
N
Y
PRINT UPDATE POLLUTION COEFF.
REPLACE CONSTANT COEFFICIENTS WITH UPDATE COEFFICIENTS
INFIL. FACTOR UNITS = 0
Y
N
READ/PRINT INFILTRATION FACTORS
COMPUTE SEWAGE FLOWS
A
A
COMPUTE POLLUTANT LOADS
PRINT FLOWS AND LOADS
WRITE FLOWS AND LOADS
STOP

FIGURE 10. PROGRAM FUNCTION FLOWCHART FOR SEWAGE

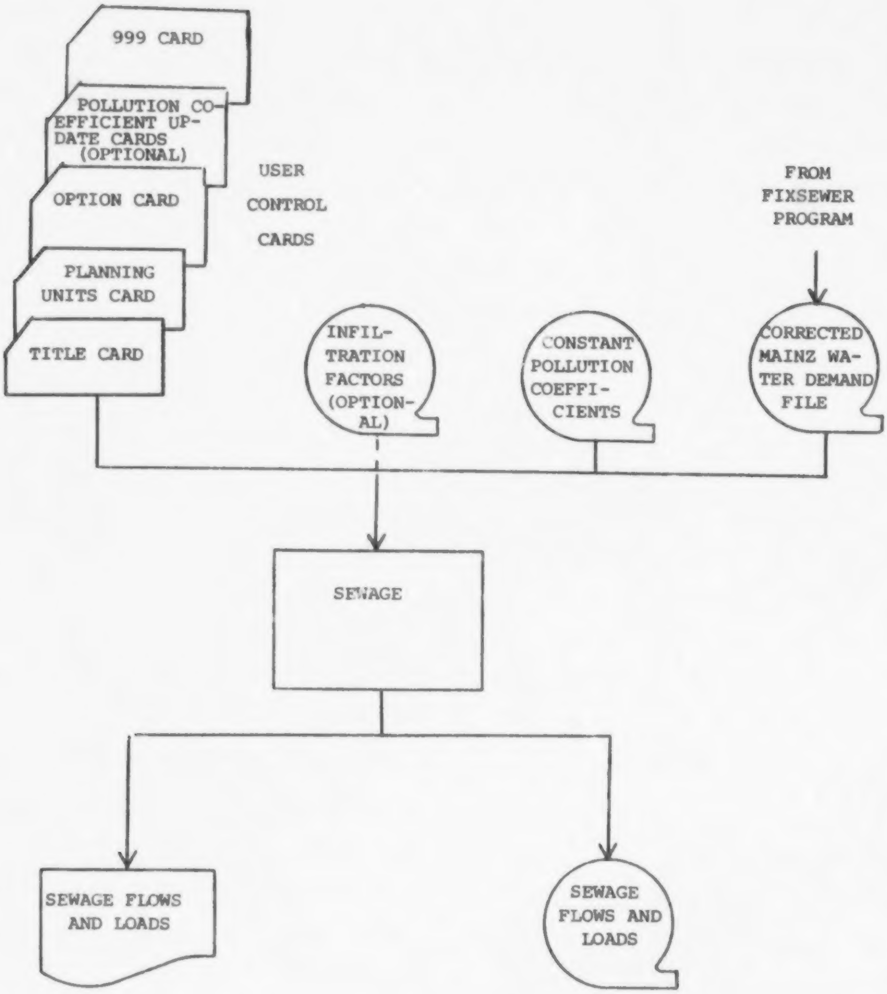

999 CARD
POLLUTION COEFFICIENT UPDATE CARDS (OPTIONAL)
OPTION CARD
PLANNING UNITS CARD
TITLE CARD
USER CONTROL CARDS
FROM FIXSEWER PROGRAM
INFILTRATION FACTORS (OPTIONAL)
CONSTANT POLLUTION COEFFICIENTS
CORRECTED MAINZ WATER DEMAND FILE
SEWAGE
SEWAGE FLOWS AND LOADS
SEWAGE FLOWS AND LOADS

FIGURE 11. INPUT-OUTPUT FLOWCHART FOR SEWAGE

DATA SPECIFICATION

Input Description

The input to the SEWAGE program consists of two required data files, one optimal file, and a set of User Control cards. The input data file is the corrected MAIN II data from the FIXSEWER program. The FORTRAN Unit number assigned to this file is coded on the Option Card.

The Constant Pollution Coefficients file, contained on disk or cards, contains domestic and commercial coefficients for each pollutant. The coefficients represent the expected concentration, in mg/l, of each pollutant.

Constant Pollution Coefficients Format

COL.	FORMAT	DATA
1-3	I3	Planning Unit Number - Maximum value of 100
4-10	F7.0	Adjustment factor (unitless) - used to modify or calibrate total average and maximum water requirements when computing flows for each planning unit.
11-17	F7.0	BOD Coefficient - Domestic expected concentration in mg/l
18-24	F7.0	BOD Coefficient - Commercial expected concentration in mg/l
25-31	F7.0	Nitrogen Coefficient - Domestic expected NO_3 (as N) concentration in mg/l
32-38	F7.0	Nitrogen Coefficient - commercial expected NO_3 (as N) concentration in mg/l
39-45	F7.0	Phosphorus Coefficient - Domestic expected $P0_4$ (as P) concentration in mg/l
46-52	F7.0	Phosphorus Coefficient - Commercial expected concentration mg/l

The optional infiltration factors file supplies the number of gallons of water in mg/d that seeps daily into the sewer system. If this file is present it must contain one record for each planning unit.

Infiltration Factors Format

COL.	FORMAT	DATA
1-3	I3	Planning Unit Number - Maximum value of 100
4-13	F10.0	Infiltration Factor - number of gallons of water infiltrating the sewer system in millions of gallons per day

Four User Control Cards supply the descriptive information for the output print lines. They also provide for optional print and updates procedure. The control card file is assigned to the DDNAME 'FT05F001'. The control cards for the program operations are:

CARD #1

Type: Title Card
Number: One - required
Purpose: Supplies report title for printed report
Format: Col. 1-80 - Free Form

CARD #2

Type: Number of Planning Units

Number: One

Purpose: Sets upper limit on number of planning units input to the program.

Format: Col. 1-5 - Integer number 1-100 for number of planning units.

Col. 6-80 - Blank

CARD #3

Type: Run Option Card

Number: One

Purpose: Gives user the option of printing the programs input data, which is the modified MAIN II data from the FIXSEWER program

Format: Col. 1-4 - Input FORTRAN unit number for modified MAIN II

5-8 - Input FORTRAN unit number of default coefficients

9-12 - Output FORTRAN unit number

13-16 - '1' if modified MAIN II data is to be printed.

'0' if modified MAIN II data is not to be printed.

17-20 - Input FORTRAN unit number of infiltration factors

21-80 - Blank

CARD #4

Type: Update Coefficient Cards

Number: One card containing 999 in Col. 1-3 must be present. Up to 100 data cards may precede this card, one per planning unit unit to be updated.

Purpose: Gives the user the option to substitute new pollution coefficients for the constant pollution coefficients.

Format: Col. 1-3 = 999 data end of update cards. Otherwise these columns confirm the number of the planning unit to be updated.

The format for completing the update is:

F7.0	Col. 4-10 - Adjustment factor
F7.0	11-17 - BOD Coefficient - domestic
F7.0	18-24 - BOD Coefficient - commercial
F7.0	25-31 - Nitrogen Coefficient - domestic
F7.0	32-38 - Nitrogen Coefficient - commercial
F7.0	39-45 - Phosphorus Coefficient - domestic
F7.0	46-52 - Phosphorus Coefficient - commercial
F7.0	53-80 - Blank

Output Descriptions

The SEWAGE program lists all User Control Cards read and prints reports that include a water requirements table for the domestic, commercial and public sectors, a pollutant coefficients table, and a sewage flow and loads table. The printfile is assigned to DDNAME 'Ft06F001'.

An output tape containing the sewage flow and loads table is produced for use as input to the TREATMENT program. The FORTRAN unit number assigned to this file is coded on the option card.

A User Option Card prints the modified MAIN II dataset (the FIXSEWER output file).

EMPDA

PURPOSE

The purpose of the EMPDA program is to convert the EMPIRIC Model output datasets into easily usable files for further processing. EMPIRIC variables are manipulated and combined with EMPDA card input data to produce new data variables by PAD such as Households per acre and median income. Forty-three variables are produced by EMPIRIC. EMPDA computes 15 new variables and places them in fixed locations in the EMPDA output format. Additional space is allocated in the output format. Additional space is allocated in the output record to permit further data additions while retaining the same 800 character record length. Other geographic areas (groupings of PADs) are also identified and placed into each PAD record and maintained in the EMPDA file for later use. The resultant output file is thus available for further processing by any programs requiring EMPIRIC data.

CHARACTERISTICS OF OPERATION

Language: PL/1

Region: 210K for the Sample Program

PROGRAM DESCRIPTION

The EMPDA program first reads and prints the parameter card. The first record of the EMPIRIC data file is read and matched against the identification information contained in the parameter card. If the ID information fails to match, an error message is printed, as well as the EMPIRIC ID, and the run is terminated.

After a successful ID match, the program reads the 37 area system cards, (146 PADs - 4 fields/card), stores and prints the data. The program then creates additional data variables, based on the EMPIRIC data and parameter card information, and creates an EMPDA output record for each of the 146 PADs. The basic 43 EMPIRIC variables are utilized to create an additional 15 variables (see Program Function Flowchart). If the print option was selected, a 'P' in column 10 of the parameter card, each output data record is formatted and printed. Jurisdictional and variable totals are computed and the PAD record is stored for later output in PAD sequence number order. After all 146 PADs have been processed, grand totals are accumulated by variable and jurisdiction and a summary report produced. The EMPDA file is then written out on tape in ascending PAD sequence number order (file format name EMPDA). Selected metropolitan summaries are printed and processing ends.

SAMPLE SETUP:
See Input-Output Flowchart

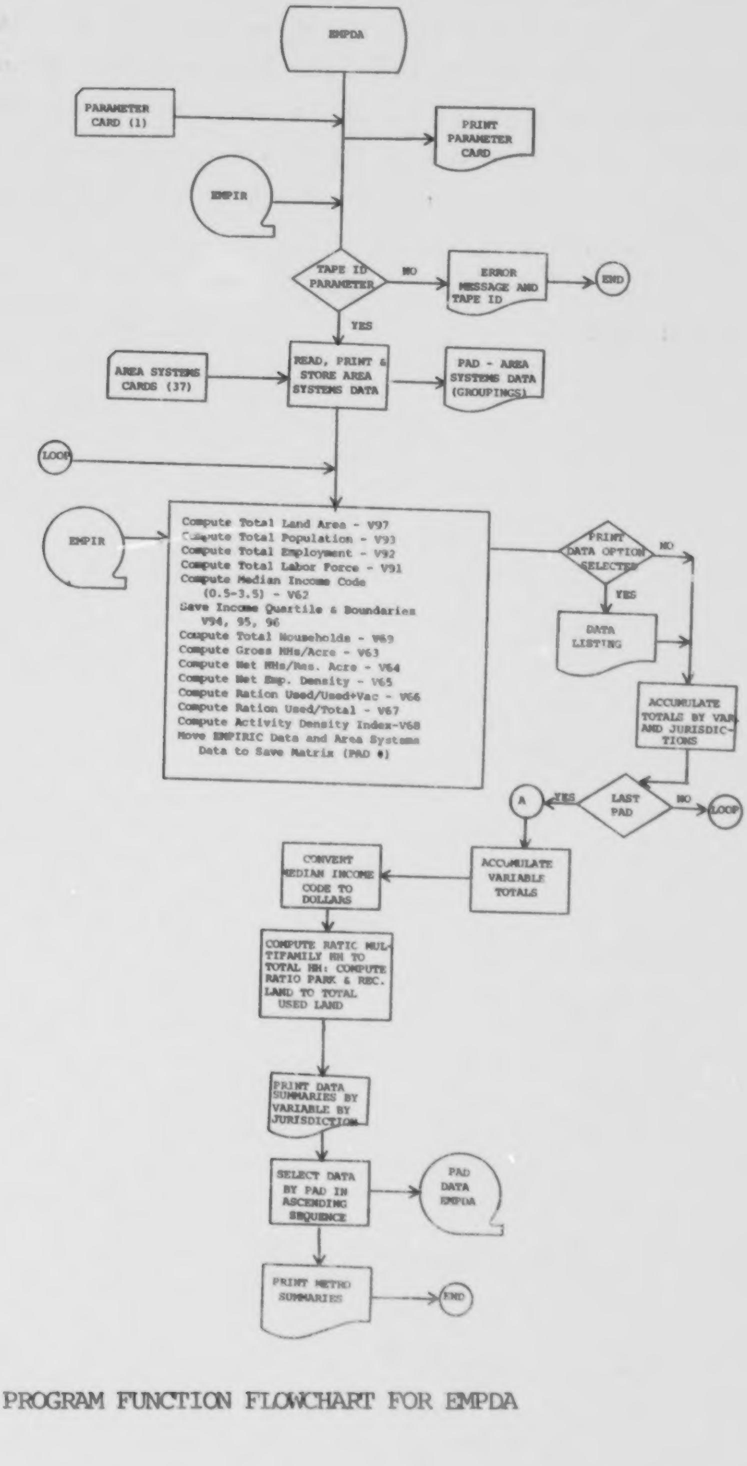

EMPDA
PARAMETER CARD (1)
PRINT PARAMETER CARD
EMPIR
TAPE ID PARAMETER
NO
ERROR MESSAGE AND TAPE ID
END
YES
AREA SYSTEMS CARDS (37)
READ, PRINT & STORE AREA SYSTEMS DATA
PAD - AREA SYSTEMS DATA (GROUPINGS)
LOOP
EMPIR
Compute Total Land Area - V97
Compute Total Population - V93
Compute Total Employment - V92
Compute Total Labor Force - V91
Compute Median Income Code (0.5-3.5) - V62
Save Income Quartile & Boundaries V94, 95, 96
Compute Total Households - V69
Compute Gross HHs/Acre - V63
Compute Net HHs/Res. Acre - V64
Compute Net Emp. Density - V65
Compute Ration Used/Used+Vac - V66
Compute Ration Used/Total - V67
Compute Activity Density Index-V68
Move EMPIRIC Data and Area Systems Data to Save Matrix (PAD #)
PRINT DATA OPTION SELECTED
NO
YES
DATA LISTING
ACCUMULATE TOTALS BY VAR. AND JURISDICTIONS
A
YES
LAST PAD
NO
LOOP
ACCUMULATE VARIABLE TOTALS
CONVERT MEDIAN INCOME CODE TO DOLLARS
COMPUTE RATIO MULTIFAMILY HH TO TOTAL HH: COMPUTE RATIO PARK & REC. LAND TO TOTAL USED LAND
PRINT DATA SUMMARIES BY VARIABLE BY JURISDICTION
SELECT DATA BY PAD IN ASCENDING SEQUENCE
PAD DATA EMPDA
PRINT METRO SUMMARIES
END

FIGURE 12. PROGRAM FUNCTION FLOWCHART FOR EMPDA

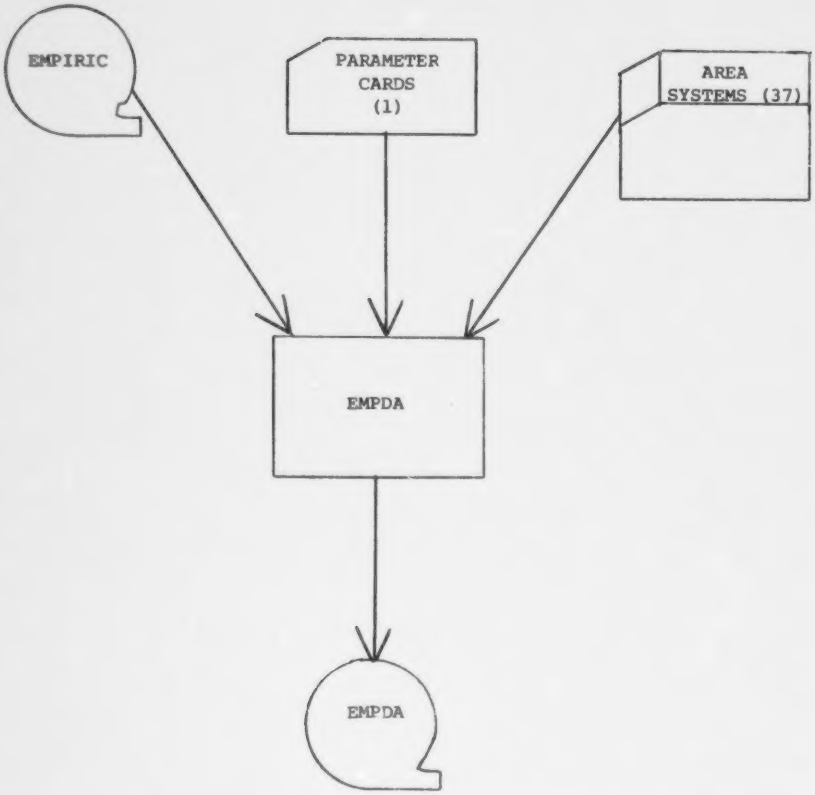

EMPIRIC
PARAMETER CARDS (1)
AREA SYSTEMS (37)
EMPDA
EMPDA

FIGURE 13. INPUT-OUTPUT FLOWCHART FOR EMPDA

DATA SPECIFICATION

Input Descriptions

There is one major input file to EMPDA, the raw EMPIRIC dataset as generated by the EMPIRIC Activity Allocation Model. The format of this file is EMPIR (see Appendix B). The DD NAME for this file is AAI. Other inputs are as follows:

EMPDA Parameter Card

	Data Card Cols:	
Required ID Match EMPIRIC Dataset	1-3	1st PAD Dist bbl from EMPIRIC
	C4	Blank
	5-6	Forecast Year
	7-8	Data Set # - Alt Tested
	9	Run Number
	10	'P' if each PAD Variable should be printed
	12-19	Low $ Median
	20-27	Low/Low Mid $ Boundary
	28-35	Middle $ Boundary
	36-43	Upper Mid/Upper $ Boundary
	44-51	Upper $ Median
	73-80	Date MM/DD/YY

EMPDA Area Systems Cards

1-3	PAD Number (001-875)
4	Blank
5-7	PAD Sequence Number (001-146)
8	Blank
7-11	TPB Superdistrict Number (001-052)
12	Blank
13-15	Density Area Code (01, 02, 11, 12)
16	Blank
17-19	EPA Areas (001-027)
20 Blank	

EMPDA Area Systems Cards

1-3	PAD Number (001-875)
4	Blank
5-7	PAD Sequence Number (001-146)
8	Blank
7-11	TPB Superdistrict Number (001-052)
12	Blank
13-15	Density Area Code (01, 02, 11, 12)
16	Blank
17-19	EPA Areas (001-027)
20 Blank	

Above repeated 4 data fields per card 37 cards for 146 PAD's

Output Descriptions

The EMPDA program writes one output data file (format EMPDA) The DD NAME for this file is AAO. An optional output is a listing of all output data variables. Standard printer output includes:

- Display of Parameter Card
- Any Error conditions encountered
- Summary Printout of Variables by Jurisdiction
- Metropolitan Averages of Selected Indicators.

PRESTORM

PURPOSE

Prestorm prepares data for the Stormwater Management Model. The model allocates EMPIRIC population and land use from the Policy Analysis Districts (PAD) to watersheds using a table prepared by planimetering the intersections of each of the areas. In doing this, the assumption was that population was uniformly distributed across the PAD and that planimetering the areas was an adequate method for estimating population by watershed. PRESTORM applies correlation equations that relate the densities of activities from EMPIRIC output to imperviousness for use in the Stormwater Management Model. PRESTORM also calculates necessary physical watershed data and inserts information on the type of storm to be simulated for use in stormwater prediction in the subsequent model.

PRESTORM allows updates of input materials or the use of previously calculated values.

CHARACTERISTICS OF OPERATION

Language:	IBM FORTRAN IV (G Level)
Region:	Region size of at least 176K. A minimum of one disk or two tape units are necessary, as well as one 132 character line printer.

PROGRAM DESCRIPTION

The PRESTORM model reads a series of User Control Cards and a tape/disk file, either an EMPDA file or optionally a PRESTORM runoff matrix file, and writes a tape or disk file that can be input to the stormwater runoff model without any additional modifications. The optional output of PRESTORM is a file, the Runoff Matrix File, which can be used as input in place of an EMPDA data set.

The operation of the program begins with the processing of the User Control Cards. As each card is read, it is validated for proper format and sequence. A Control Card containing format errors or appearing out of sequence will be identified by a printed message. The program will terminate if any of the aforementioned conditions occur.

The Title Card and Card Type 1 are read and printed. If an EMPDA file was selected for input, subroutine I2INIT is performed. I2INIT inserts blanks or zeroes into the runoff matrix as required. The runoff matrix is an array that holds all the data values for the executive and runoff control block card groups that are input to the stormwater runoff model. If the optional input, the runoff matrix file, was selected it is input directly into the runoff matrix.

If the runoff matrix is to be updated, a Card Type #2 would be the next Control Card processed. Type 2 or 5 Cards contain new values to be entered into the runoff matrix. If any value is to be set equal to zero, a minus one (-1) is copied for that value. The update is completed and control is returned to the main program where the next Control Card is read.

The Card Type #3, if supplied, invokes subroutine I2DEF. This program enters default values into the runoff matrix for runoff card groups 5, 7 and 18.

If the EMPDA file was selected as input, the next control card transfers program control to subroutine I2EMP. I2EMP processes the EMPDA file and the user file in allocation Policy Analysis Districts to watersheds. Population, households and employment data is aggregated to watersheds and either entered directly into the runoff matrix or used to compute additional data items. The equation derived at COG(17) to estimate a measure of imperviousness from population density is applied as is the equation estimating total length of gutters.

The results of these computations are stored in the Runoff Matrix and control is returned to the main program.

The Card Type #5 would occur next if the user desires to override any of the data items calculated from the EMPDA data. The same operations are performed for a Card Type #5 as a Card Type #2.

The Card Type #6 directs the program to read additional input in the form of Runoff Cards Groups. This data is appended to the standard program output card groups and is not verified or inspected for format or logic errors.

The output operations are signaled by the use of Card Type #7's. The runoff matrix is formated to correspond to the required card group formats for the executive and the runoff blocks of the Stormwater Management Model. The formated data can be printed and/or written to a tape or disk file to be read directly by the stormwater runoff model. The Runoff Matrix itself can be written to a tape or disk file and used as input to a future run of the PRESTORM model.

The Card Type #7's must be followed by a Card Type #9 to signify the end of the User Control Cards and to terminate the program operation. There is no Card Type #8.

SAMPLE SETUP: See Input - Output Flowchart.

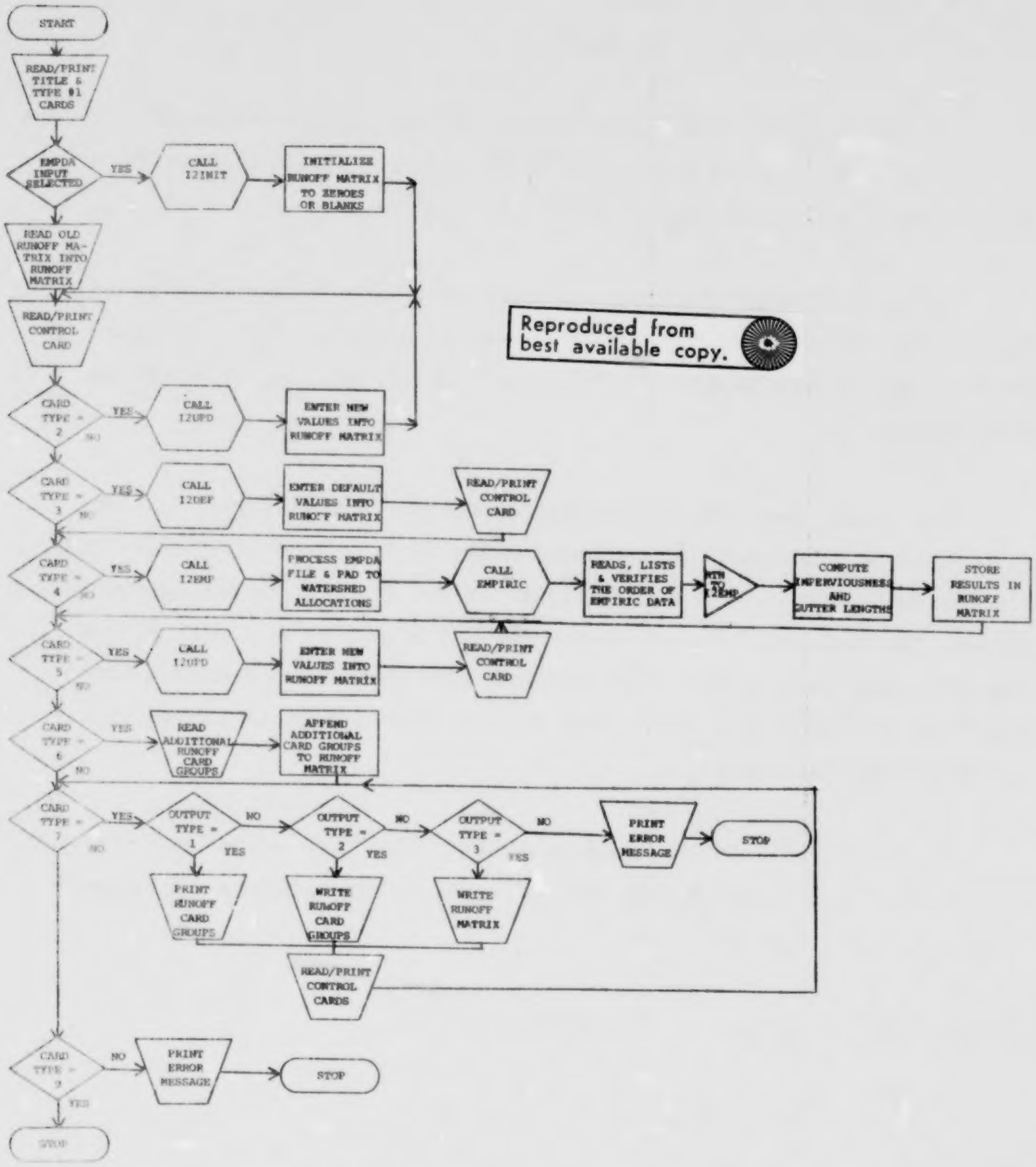

START
READ/PRINT TITLE & TYPE #1 CARDS
EMPDA INPUT SELECTED
YES
CALL I2INIT
INITIALIZE RUNOFF MATRIX TO ZEROES OR BLANKS
READ OLD RUNOFF MA-TRIX INTO RUNOFF MATRIX
READ/PRINT CONTROL CARD
CARD TYPE = 2
YES
NO
CALL I2UPD
ENTER NEW VALUES INTO RUNOFF MATRIX
CARD TYPE = 3
YES
NO
CALL I2DEF
ENTER DEFAULT VALUES INTO RUNOFF MATRIX
READ/PRINT CONTROL CARD
CARD TYPE = 4
YES
NO
CALL I2EMP
PROCESS EMPDA FILE & PAD TO WATERSHED ALLOCATIONS
CALL EMPIRIC
READS, LISTS & VERIFIES THE ORDER OF EMPIRIC DATA
RTN TO I2EMP
COMPUTE IMPERVIOUSNESS AND GUTTER LENGTHS
STORE RESULTS IN RUNOFF MATRIX
CARD TYPE = 5
YES
NO
CALL I2UPD
ENTER NEW VALUES INTO RUNOFF MATRIX
READ/PRINT CONTROL CARD
CARD TYPE = 6
YES
NO
READ ADDITIONAL RUNOFF CARD GROUPS
APPEND ADDITIONAL CARD GROUPS TO RUNOFF MATRIX
CARD TYPE = 7
YES
NO
OUTPUT TYPE = 1
NO
YES
OUTPUT TYPE = 2
NO
YES
OUTPUT TYPE = 3
NO
YES
PRINT ERROR MESSAGE
STOP
PRINT RUNOFF CARD GROUPS
WRITE RUNOFF CARD GROUPS
WRITE RUNOFF MATRIX
READ/PRINT CONTROL CARDS
CARD TYPE = 9
NO
YES
PRINT ERROR MESSAGE
STOP
STOP

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FIGURE 14. PRESTORM PROGRAM FUNCTION FLOWCHART

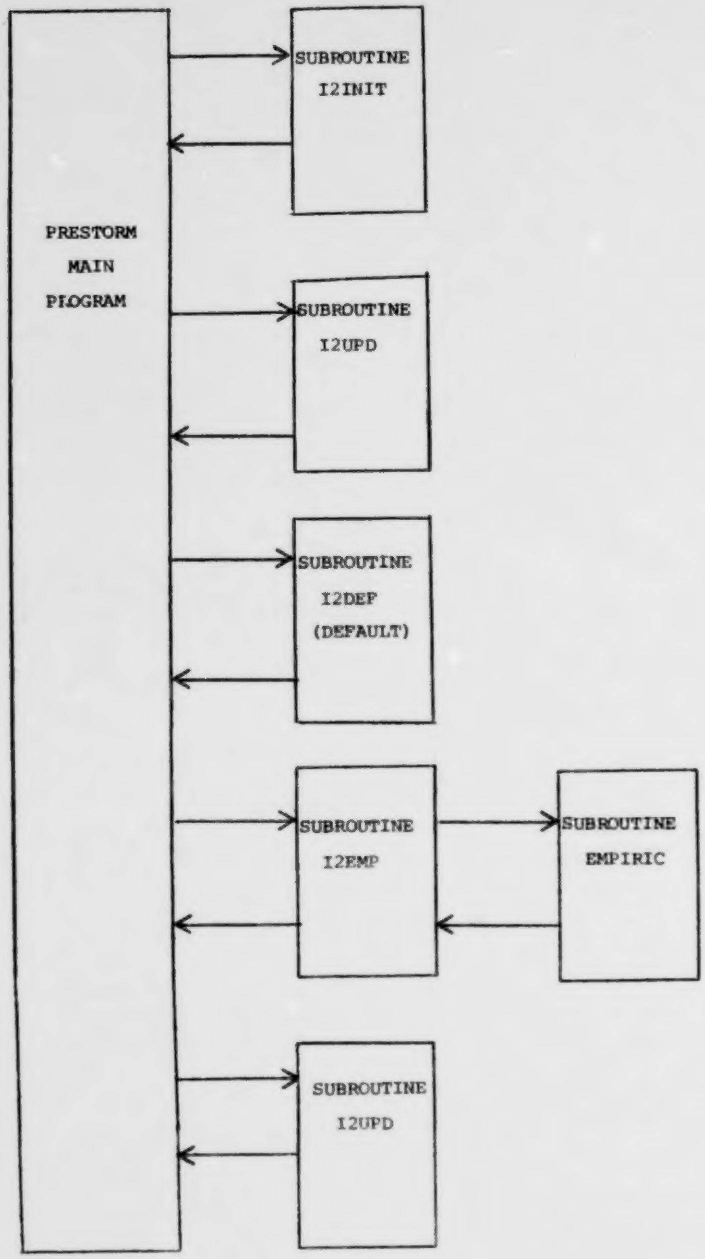
PRESTORM
MAIN
PROGRAM
SUBROUTINE
I2INIT
SUBROUTINE
I2UPD
SUBROUTINE
I2DEF
(DEFAULT)
SUBROUTINE
I2EMP
SUBROUTINE
EMPIRIC
SUBROUTINE
I2UPD

FIGURE 15. PRESTORM SUBROUTINE LINKAGE

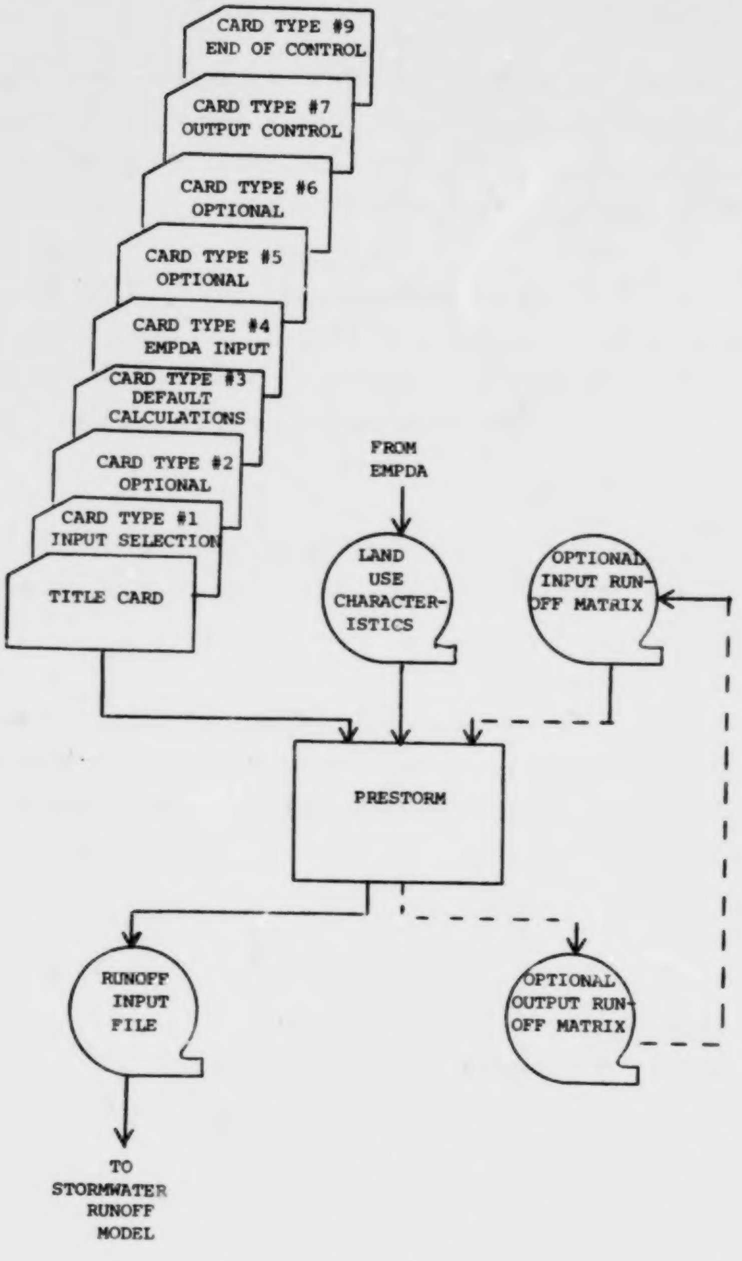
CARD TYPE #9
END OF CONTROL
CARD TYPE #7
OUTPUT CONTROL
CARD TYPE #6
OPTIONAL
CARD TYPE #5
OPTIONAL
CARD TYPE #4
EMPDA INPUT
CARD TYPE #3
DEFAULT
CALCULATIONS
CARD TYPE #2
OPTIONAL
CARD TYPE #1
INPUT SELECTION
TITLE CARD
FROM
EMPDA
LAND
USE
CHARACTER-
ISTICS
OPTIONAL
INPUT RUN-
OFF MATRIX
PRESTORM
RUNOFF
INPUT
FILE
OPTIONAL
OUTPUT RUN-
OFF MATRIX
TO
STORMWATER
RUNOFF
MODEL

FIGURE 16. PRESTORM INPUT-OUTPUT FLOWCHART FOR PRESTORM

DATA SPECIFICATION

Input Description

The PRESTORM program input consists of a series of User Control Cards, a User Supplied file and a tape or disk file output by the EMPDA program. An alternate Input, replacing the EMPDA file, is a Runoff Matrix file generated in a previous run of the PRESTORM model.

The data file created by the EMPDA program from the EMPIRIC data contains summarized land use characteristics for each planning analysis district. This file must be sorted prior to its use as input to the PRESTORM model. The sort is ascending in the following order: COL. 2, COL. 1 then COL. 3.

The optional runoff matrix file is a file produced by an earlier run of the prestorm program. The file contains all the data values needed to construct the input file for the stormwater runoff model.

The User Control cards supplied to the PRESTORM model must be submitted in the order that they are described here. Failure to do so will cause the program to terminate. The function and format of each of the nine card types is as follows:

Type:	Title Card		
Number:	One - Required		
Purpose:	Supplies Report Title For Printed Output		
Format:	COLS	Format	Data
	1-8	20A4	Free Form Descriptive Data

Type: Card Type #1

Number: 1 Only

Purpose: Specify Type of Input

Format:	COLS	Format	Data
	1	I1	Card ID '1'
	7	I1	1= EMPDA File Input 2= Old PRESTORM Runoff Matrix Input
	14-15	I2	FORTRAN unit number of Runoff Matrix if COL. 7=2

Type: Card Type #2 or #5

Number: As Required

Purpose: Supply or update storm and watershed data

Format:	COLS	Format	Data
	1	I1	2= Update matrix prior to Default and EMPA Calculations 5= Update Matrix after Default and EMPDA Calculations
	5		R= Enter Runoff Block Data E= Enter Executive Block Data B= Enter Runoff Data Coefficients
	6-7	I2	Number of card to be updated Runoff Block: 1-18 Executive Block: 1-6
	14-15	I2	Number of Update cards following this card
	16-20	I5	Number of Watersheds (Optional) used if COL.5=B

Type: Card #3

Number: 1 only (Optional)

Purpose: This card initiates the default calculations

Format:

COLS	Format	Data
1	I1	'3' Card Type ID

Type: Card #4

Number: 1 only

Purpose: Directs program to read an EMPDA data set

Format:

COLS	Format	Data
1	I1	'4' Card Type ID
7	I1	1= Print EMPDA data for each policy analysis district
10-11	I2	0= Do not print EMPDA data FORTRAN unit number assigned to EMPDA data set.

Type: Card Type #6

Number: 1 only (Optional)

Purpose: Permit the input of additional data - a second set of runoff data or data to be input to the graphing programs

Format:

COLS	Format	Data
1	I1	'6' Card type ID FORTRAN
10-11	I2	FORTRAN unit number assigned to additional data set
14-15		Number of data cards in the additional data set.

Type: Card Type #7

Number: As Required

Purpose: Specify the type and FORTRAN unit number of each output.

Format:

COL	Format	Data
1	I1	'7' Card Type ID 1= Print runoff matrix 2= Write stormwater runoff input data matrix 3= Write runoff matrix - optional input to PRESTORM

10-11	I2	FORTRAN unit number assigned to output file if COL 7= 2 or 3

Type: Card Type #9

Number: 1 only

Purpose: Indicate end of User Control Cards.

Format:

COL	Format	Data
1	I1	'9' Card Type ID

The user supplied file contains records allocating a certain percentage of a Policy Analysis District to a watershed.

The maximum number of records for this file is one thousand. This file must be supplied when the EMPDA data set is selected as input. It is assigned to the FORTRAN unit number 20.

Format:

COLS	Format	Data
1-2	I2	Watershed number or '99' if last record
5-7	I3	Policy Analysis District
10-12	I3	Percentage of PAD allocated to watershed.

Output Description

The PRESTORM model prints the User Control Cards and writes a tape or disk file that can be input directly to the Stormwater Management Model. An optional output is a tape or disk file containing the runoff matrix.

The Stormwater Management Model input file contains, in card image format, the eighteen card groups required by the runoff block and first six card groups required by the executive block of the model.

The runoff matrix file contains all the data values used to construct the runoff model input file. This file is the optional input to the PRESTORM model.

Printed output consists of a listing of all User Control Cards and, optionally, the EMPDA input data and/or the stormwater runoff model data produced by PRESTORM. The print file is assigned to FORTRAN unit number 6.

STORMWATER RUNOFF COMPONENT

PURPOSE

The stormwater runoff component of the Framework system is designed to simulate the stormwater runoff which occurs in a drainage basin during a specified rainfall pattern. For the design storm the quantity and quality of the stormwater over time is calculated. This computation provides essential data for planning and design of flooding and pollution control strategies in the basin.

The model simulates the watershed as a series of sub-catchments connected by gutters, determines precipitation, infiltration to the soil, surface water detention and flow over the land. The accumulation and subsequent washoff of dust, dirt, and BOD are also calculated and combined with quantity calculations to determine concentration. Hydrographs of water quantity at specified points in the system and pollutographs are outputs of the model.

MODEL INPUTS

Precipitation

The model requires a rainfall hyetograph (inches per hour by time interval) time history of a storm — which is determined from analyses of Weather Bureau data.

Description of Watershed

The following items are required to adequately describe the physical features of a watershed which affect the rainfall runoff:

- Watershed
  - Area (acres)
  - Length: width ratio
  - Overland flow slope

Stream by Watershed
  - Length of main stream (ft.)
  - Width of main stream (ft.)
  - Slope of main stream (ft.)
  - Coefficient of roughness (Manning's n)

Land Use by Watershed, each expressed as a percentage of the total area,
  - Residential
  - Commercial
  - Industrial
  - Undeveloped
  - Imperviousness and other physical data
  - Impervious area coefficient of roughness
  - Impervious area detention depth (in.)
  - Pervious area coefficient of roughness
  - Pervious area detention depth (in.)
  - Pervious maximum infiltration rate (in./hr.)
  - Pervious area minimum infiltration rate (in./hr.)
  - Pervious area decay rate of infiltration (sec-1)
  - Curb Length (ft./land use area) by watershed

Watershed and stream geometry and physical features are determined by analysis of U.S. Geological Survey topographic maps and knowledge of the area to be studied. Land use for each watershed is determined from the Community Development Component which is retabulated into watersheds by the interface program PRESTORM. The percentage of land by land use is used in the model to determine the average accumulation rate of pollutants on the land surface. This rate varies by land use. Of all the factors which describe a watershed, sensitivity analyses have shown that imperviousness and curb length have the greatest impact on rainfall runoff quantities and quality.[17] Both of these parameters may be calculated from manual reductions of aerial photographs--measuring the length of roads and areas of imperviousness. This process is time consuming and in addition cannot be used for analysis of future development patterns. As an alternate technique analysis at the Council of Governments [17] has shown that imperviousness and curb length can be estimated with a relatively high degree of reliability (r=0.9) from household and employment densities. More recent analysis of the correlation data for this region between measured imperviousness and curb length to household and employment densities has yielded the following relationship.

$$I = 96.6 - 18.7\ (0.8927)^{ED} - 54.2\ (07.7889)^{HD}$$

$$C = 427.4 - 388.1\ (0.6899)^{HD}$$

Where

I = Imperviousness (percent)

ED = Employment Density (Employment percent)

HD = Household Density (Household percent)

C = Curb length (ft per acre)

MODEL CALCULATIONS

The model calculates the hydrograph by a step-by-step accounting of rainfall, infiltration, detention and flow. Rainfall is added to each catchment according to the input hyctograph (rainfall in inches per hour) by the procedues used in the EPA Storm Water Management Model,[18] as summarized below:

1. Rainfall is added to the subcatchment according to the specified hyetograph

$$D_1 = D_t + R_t \Delta t \qquad (1)$$

Where D_1 = Water depth after rainfall

D_t = Water depth of the subcatchment at time, t

R_t = Intensity of rainfall in time interval, Δt

---

[17] P. Graham, L. Costello, and H. Mallon, "Estimation of Imperviousness and Specific Curb Length for Forecasting Stormwater Quality and Quantity," Journal of the Water Pollution Control Federation, (April, 1974).

2. Infiltration is computed by Horton's exponential functional and is subtracted from water depth existing on the subcatchment,

$$I_t = f_o + (f_i - f_o)\, e^{-at} \qquad (2)$$

and

$$D_2 = D_1 - I_t \Delta t \qquad (3)$$

Where f_o, f_i and a are coefficients in Horton's equation

3. If the resulting water depth of the subcatchment, D_2, is larger than the specified detention requirement, D_d, an outflow rate is computed using Manning's equation,

$$V = \frac{1.49}{n} (D_2 - D_d)^{2/3} S^{1/2} \qquad (4)$$

and

$$Q_w = V\ W\,(D_2 - D_d) \qquad (5)$$

where V = Velocity
n = Manning's coefficient
s = Ground slope
W = Width
Q_w = Outflow rate

4. The continuity equation is solved to determine the water depth of the subcatchments, resulting from the rainfall, infiltration, and outflow,

$$D_{t+\Delta t} = D_2 - (Q_w/A)\Delta t \qquad (6)$$

where A is the surface area of the subcatchment

5. Steps 1 to 4 are repeated until computations for all subcatchments are completed.

6. The inflow (Q_{in}) to a gutter is computed as a summation of outflow from tributary subcatchments ($Q_{w,i}$) and flow rate of immediate upstream gutters ($Q_{q,i}$).

$$Q_{in} = \Sigma Q_{w,i} + \Sigma Q_{g,i} \tag{7}$$

7. The inflow is added to raise the existing water depth of the gutter according to its geometry,

$$Y_1 = Y_t + (Q_{in} / A_s) \Delta t \tag{8}$$

where Y_1 and Y_t = Water depth of the gutter
A_s = Mean water surface area between Y_1 and Y_t

8. The outflow is calculated for the gutter using Manning's equation,

$$V = \frac{1.49}{n} R^{2/3} S_i^{1/2} \tag{9}$$

and

$$Q_g = V A_c \tag{10}$$

where R = Hydraulic radius
S_i = Invert slope
A_c = Cross-sectional area at Y_1

9. The continuity equation is solved to determine the water depth of the gutter, resulting from the inflow and outflow.

$$Y_{t+\Delta t} = Y_1 + (Q_{in} - Q_g)\Delta t / A_s \tag{11}$$

10. Steps 6 to 9 are repeated until all the gutters are finished.

11. The flows, reaching the points of concern, are added to produce a hydrograph coordinate along the time axis.

SPLIT

PURPOSE

The stormwater runoff component determines the amount of stormwater which flows from a watershed by means of a natural drainage system. This 'natural flow' from a watershed is reduced proportionately to the coverage of a watershed by storm sewers and/or combined storm and sanitary sewers. The SPLIT program is the vehicle used to allocate the stormwater runoff flows and loads to separate files of sewered areas where flows are potentially treatable, or to unsewered areas where natural flows and loads will be discharged directly into streams. These discharges are analyzed for input to the hydrodynamic model in the receiving water component. This distinction is made so that different assumptions about travel and treatment can be made at a later stage in the chain of models.

CHARACTERISTICS OF OPERATIONS

Language: IBM FORTRAN IV (G Level)

Computer Requirements:

Split requires a minimum of 50K in which to execute. At least one disk unit or three tape units are required for the input and output files. The printed reports require one 132 character line printer.

PROGRAM DESCRIPTION

The SPLIT program inputs two files, the stormwater runoff file produced in the stormwater runoff component and the constant split percentages file (a user file containing for each watershed the percentage of stormwater runoff entering the sewer system), and one card file containing two User Control Cards. The program output consists of two files containing runoff flows and loads, one for the sewered runoff and the other for unsewered or 'natural' runoff. Printed reports listing the User Control Cards, the tabel of constant split percentages, the runoff flows and loads from the stormwater runoff component, and a table of the split runoff flows and loads.

The SPLIT program was written to perform the computations for 65 watershed areas. If the number of watersheds output by the stormwater runoff component is not equal to 65, the program must be modified to accommodate the new number of watershed areas.

The program begins operation by initializing the number of watersheds to be processed to 65. The User Control Card file is read and the first card, the Title Card, is printed. Second, the Control Card is read and printed. It assigns FORTRAN unit numbers to the input and output files.

The constant split percentages file is read into an array and printed in report form. This file contains, for each watershed, the percentage of the flow and the percentage of the three pollutants, BOD, Nitrogen and Phosphorus that enter the sewer system in that watershed.

The stormwater runoff file is read, entered into an array, and then printed in report form. The runoff flows which input in units of cubic feet are converted to gallons.

The sewered stormwater runoff flows and loads for all watersheds are now calculated. The sewered flow of a watershed is computed as:

$$\mathrm{SFLOW}_W = \left[\mathrm{RFLOW}_W\right]\left[\mathrm{SPCT}_W\right]$$

Where: SFLOW_W = Sewered runoff in gallons to receive treatment
RFLOW_W = Stormwater runoff for watershed in gallons

SPCT_W = Percentage of runoff collected into the sewer system in watershed W

The sewered pollutant loads of a watershed are computed as:

$$\mathrm{SLOAD}_{WJ} = \left[\mathrm{RLOAD}_{WJ}\right]\left[\mathrm{SPCET}_{WJ}\right]$$

Where: $SLOAD_{WJ}$ = Load of pollutant J in Watershed W to receive treatment

$RLOAD_{WJ}$ = Runoff load of pollutant J in Watershed W

$SPCT_{WJ}$ = Percentage of pollutant J in Watershed W collected into sewer system

The sewered or 'natural' flows and loads are the differences between the runoff flows and loads and the sewered flows and loads. The calculations having been completed, the output function of the program begins.

The output tape or disk files are written, one containing the sewered flows and loads, the other the unsewered, and a report for both sewered and unsewered flows and loads is printed. Program operation terminates at the completion of the output process with a printed message to confirm a successful run.

SAMPLE SETUP: See Input-Output Flowchart

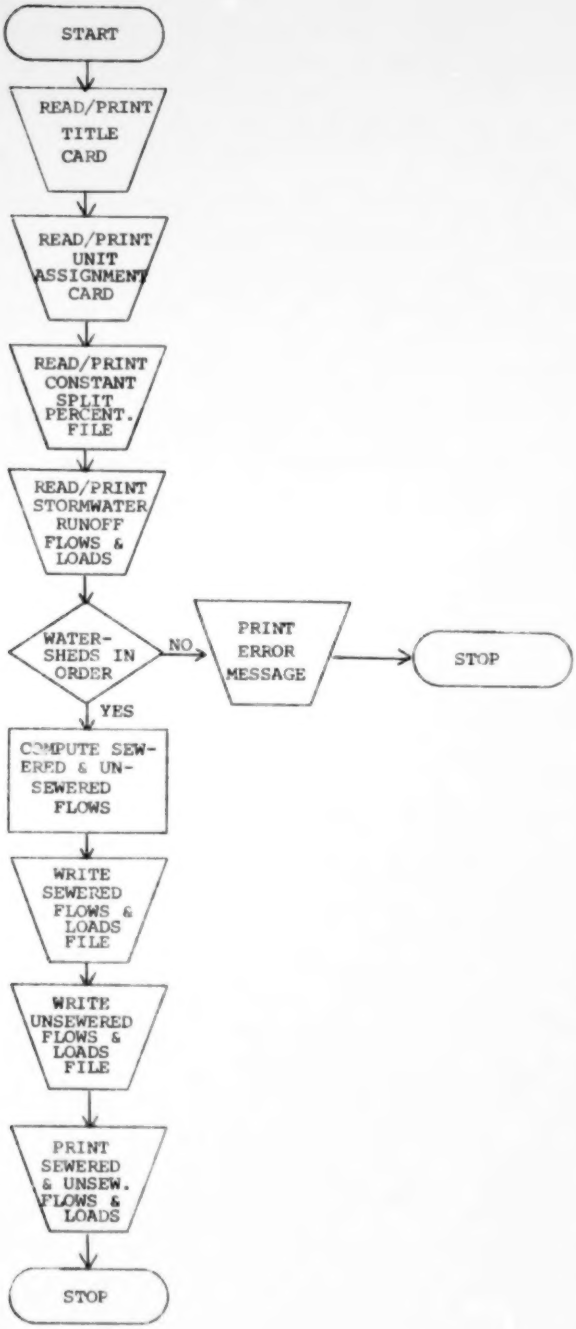
START
READ/PRINT TITLE CARD
READ/PRINT UNIT ASSIGNMENT CARD
READ/PRINT CONSTANT SPLIT PERCENT. FILE
READ/PRINT STORMWATER RUNOFF FLOWS & LOADS
WATER-SHEDS IN ORDER
NO
PRINT ERROR MESSAGE
STOP
YES
COMPUTE SEWERED & UN-SEWERED FLOWS
WRITE SEWERED FLOWS & LOADS FILE
WRITE UNSEWERED FLOWS & LOADS FILE
PRINT SEWERED & UNSEW. FLOWS & LOADS
STOP

FIGURE 17. PROGRAM FUNCTION FLOWCHART FOR SPLIT

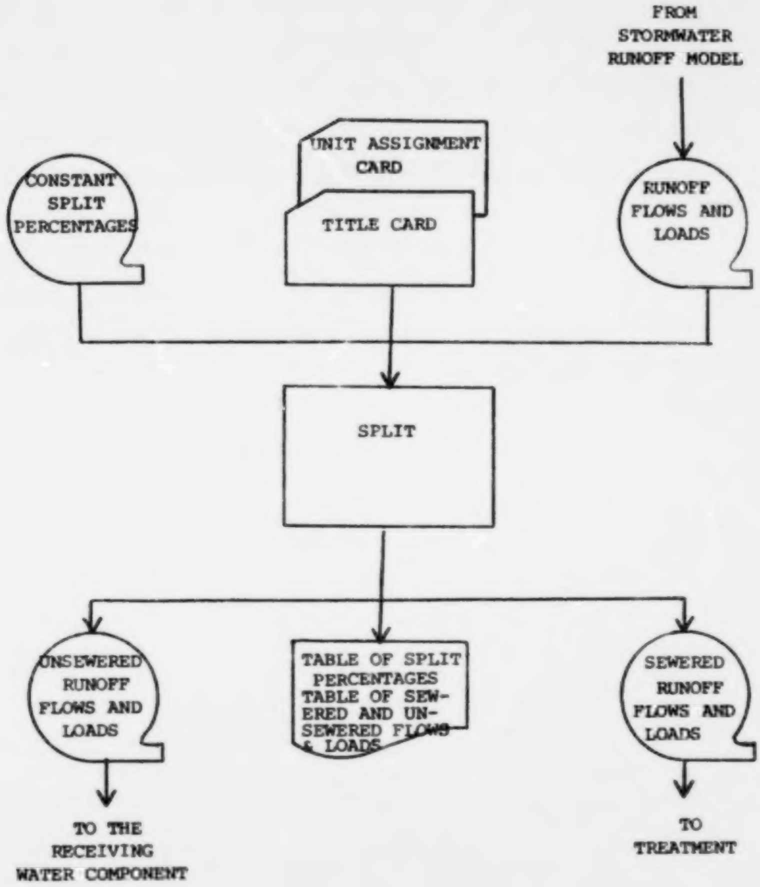
FROM
STORMWATER
RUNOFF MODEL
CONSTANT
SPLIT
PERCENTAGES
UNIT ASSIGNMENT
CARD
TITLE CARD
RUNOFF
FLOWS AND
LOADS
SPLIT
UNSEWERED
RUNOFF
FLOWS AND
LOADS
TABLE OF SPLIT
PERCENTAGES
TABLE OF SEW-
ERED AND UN-
SEWERED FLOWS
& LOADS
SEWERED
RUNOFF
FLOWS AND
LOADS
TO THE
RECEIVING
WATER COMPONENT
TO
TREATMENT

FIGURE 18. INPUT-OUTPUT FLOWCHART FOR SPLIT

DATA SPECIFICATION

Input Description

The split program reads one tape or disk file containing the flows and loads estimated for each watershed by the stormwater runoff component, and one tape, disk, or card file containing, for each watershed, the percentage of stormwater runoff entering the sewer system. Two user control cards complete the input requirements.

Runoff flows and loads file is produced by the Stormwater Runoff Component. It contains the flows and loads expected to result from the occurrence of a storm event defined by its intensity and duration. The file is assigned to the FORTRAN unit number coded on the unit assignment card.

Constant split percentage file is a user created file containing the percentage of runoff entering the sewer system. These percentages are applied to the runoff flows and loads to compute the sewered and unsewered runoff flows and loads.

CONSTANT SPLIT PERCENTAGES FILE FORMAT

COLS.	FORMAT	DATA
1-3	I3	Watershed number (Maximum 65)
4-10	F7.3	Percent of flow collected into storm or combined sewer system
11-17	F7.3	Percent of BOD load collected into storm or combined sewer system
18-24	F7.3	Percent of Nitrogen load collected into storm or combined sewer system

25-31	F7.3	Percent of Phosphorus load collected into storm or combined sewer system
32-80	49X	Blank

The percentages are coded in the form XXX.XXX, i.e, 25 percent would be coded 25.0

Two User Control Cards are required. One provides descriptive information for the printed report, the other assigns FORTRAN unit numbers to the input and output files.

CARD #1

Type: Title Card

Purpose: Supply descriptive information for printed reports

Number: 1 only

Format: Col. 1-80 - Free form comments to describe stormwater runoff data

CARD #2

Type: Unit Assignment Card

Purpose: Assign FORTRAN unit numbers to the input and output files

Number: 1 only

Format:

Cols.	Format	Data
1-4	I4	Unit number of constant split percentages file
5-8	I-4	Unit number of stormwater runoff file
9-12	I4	Unit number of sewered runoff file
13-16	I4	Unit number of unsewered runoff file

Output Description

The SPLIT program output consists of two tape or disk files, one containing the sewered runoff flows and loads, the other containing the unsewered runoff flows and loads, and printed reports of the input and output data.

Sewered stormwater file containing the flows and loads that enter the sewage system. These flows and loads will be treated by the waste treatment management component. The file is assigned to the FORTRAN unit number coded on the Unit Assignment Card. Unsewered stormwater runoff file containing the flows and loads that enter directly into the estuary without any treatment. The file is assigned to the FORTRAN unit number coded on the Unit Assignment Card.

A report is printed listing the sewered and unsewered loads and flows for each watershed which are used in the Receiving Water Component (See Table 8). In addition, the User Control Cards, the constant split percentages file, and the runoff flows and loads estimated by the stormwater runoff component are printed. The print file is assigned to FORTRAN unit number 6.

TREATMENT

PURPOSE

The purpose of the TREATMENT program is to provide the means to simulate alternative waste treatment management options, and to summarize their effect on the wastewater flows, loads (estimated by the Sewage Generation Component), the stormwater runoff flows and the loads (estimated by the Stormwater Runoff Component).

The combined treated sewage flows and pollutant loads calculated by the TREATMENT program are analyzed and the relevant data is extracted and prepared for use in the Receiving Water Component.

CHARACTERISTICS OF OPERATION

Language: IBM FORTRAN IV (G Level)

Region: A minimum region size of 80K is required. The program requires at least one disk or four tapes, a card reader, and a 132-character per line printer.

PROGRAM DESCRIPTION

The TREATMENT program reads two tape or disk files, (the wastewater and stormwater flows and loads), a User Control Card file, and three User Created files that may reside on card, disk or tape. These inputs provide the program with the information necessary to calculate the residual pollutant loads discharged by each sewage service area into the estuary. One output file is created, a tape or disk file containing combined treated sewage flows and loads. Printed reports of both input and output data are also produced.

The first step in the program operation is the processing of the User Control Cards. The first card, the Title Card, is read and printed. The Title Card will also be printed at the top of each report. The second card input should be the Service Areas Card. This card contains the number of planning units and watersheds that will be read from the Wastewater and Stormwater files, and the number of Sewer Service Areas that will be written to the tape or disk output file. The last User Control Card supplies the FORTRAN unit numbers for the five input files.

The three User-Created files are processed next. The Sewage Service Area Assignments file is composed of two groups of records. Each group is identified by a two-digit record identification. The first group assigns sewage service areas to watersheds while the second assigns service areas to planning units. The second user file processed is the Sewage Service Area Treatment Efficiencies file. This file contains pollutant removal efficiencies for each sewage service area. The efficiencies are represented as the percentage of each pollutant (BOD, Nitrogen, and Phosphorus) that would be removed by a treatment facility located in a sewage service area. The third file, the Description File consists of three groups of records. One group contains geographic descriptions of watersheds. The remaining groups contain planning unit and sewage service area descriptions.

The Wastewater and the Stormwater Runoff files are processed next. If the number of watersheds or the number of planning units coded on the Service Areas Card is zero, the processing of the corresponding flows and loads file is skipped. When the input operations are complete, the calculation of the treated effluent begins.

The effluent computation is a two-step process. In the first step, the flows are aggregated to sewage service areas by means of the sewage service areas assignments. In the second step, the residual pollutant loads are computed by means of the sewage service area treatment efficiencies. The process is performed twice, once to compute average treated flows and loads and once to compute maximum flows and loads. The treated flows and loads are summed to yield a table of combined treated sewage flows and loads. The resultant combined treated flows table can then be used to assist in the determination of the quantity, location and characteristics of point source discharges needed by the estuary component.

The output operation prints and writes to a tape or disk file the treated flows and loads for both the input components and the computed combined sewage effluent. The output process completes the program operation.

SAMPLE SETUP - See Input Input-Output Flow Chart

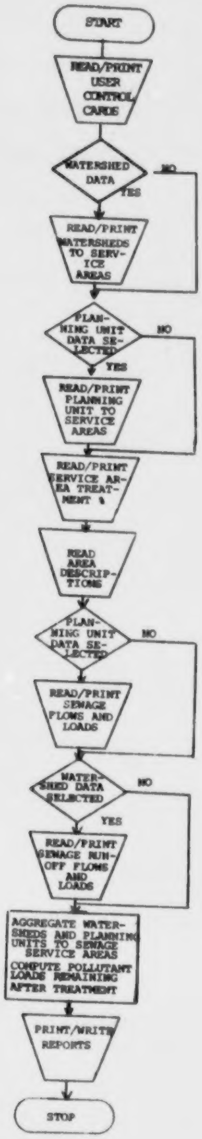
START
READ/PRINT USER CONTROL CARDS
WATERSHED DATA
NO
YES
READ/PRINT WATERSHEDS TO SERV-ICE AREAS
PLAN-NING UNIT DATA SE-LECTED
NO
YES
READ/PRINT PLANNING UNIT TO SERVICE AREAS
READ/PRINT SERVICE AR-EA TREAT-MENT %
READ AREA DESCRIP-TIONS
PLAN-NING UNIT DATA SE-LECTED
NO
READ/PRINT SEWAGE FLOWS AND LOADS
WATER-SHED DATA SELECTED
NO
YES
READ/PRINT SEWAGE RUN-OFF FLOWS AND LOADS
AGGREGATE WATER-SHEDS AND PLANNING UNITS TO SEWAGE SERVICE AREAS
COMPUTE POLLUTANT LOADS REMAINING AFTER TREATMENT
PRINT/WRITE REPORTS
STOP

FIGURE 19. PROGRAM FUNCTION FLOWCHART FOR TREATMENT

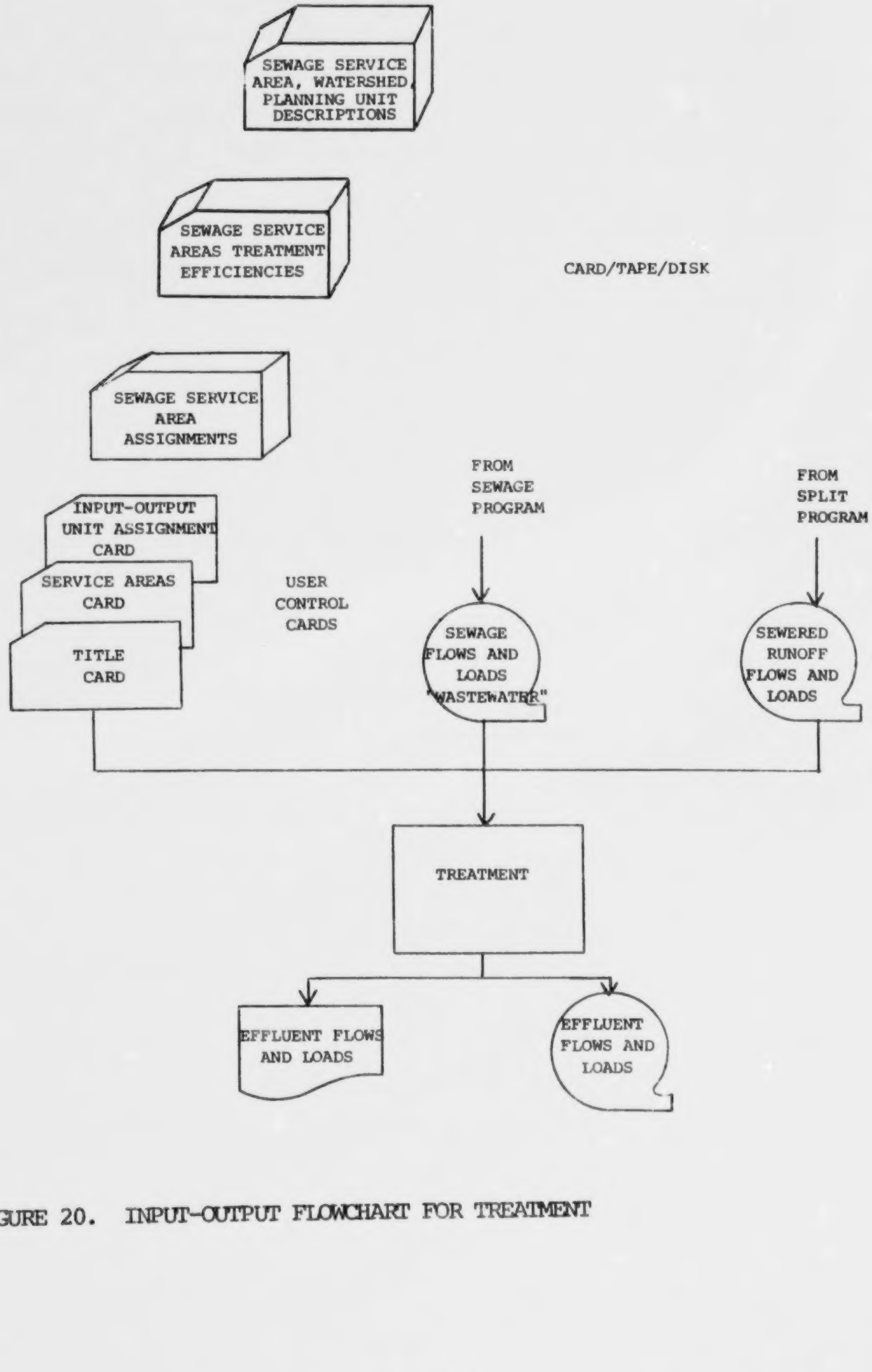
SEWAGE SERVICE AREA, WATERSHED, PLANNING UNIT DESCRIPTIONS
SEWAGE SERVICE AREAS TREATMENT EFFICIENCIES
CARD/TAPE/DISK
SEWAGE SERVICE AREA ASSIGNMENTS
INPUT-OUTPUT UNIT ASSIGNMENT CARD
SERVICE AREAS CARD
TITLE CARD
USER CONTROL CARDS
FROM SEWAGE PROGRAM
SEWAGE FLOWS AND LOADS "WASTEWATR"
FROM SPLIT PROGRAM
SEWERED RUNOFF FLOWS AND LOADS
TREATMENT
EFFLUENT FLOWS AND LOADS
EFFLUENT FLOWS AND LOADS

FIGURE 20. INPUT-OUTPUT FLOWCHART FOR TREATMENT

DATA SPECIFICATION

Input Description

The TREATMENT program input consists of one card file (the User Control Cards) and two tape or disk files (the output file from the SEWAGE program and the sewered output file form the SPLIT program). In addition, three user-created input datasets may reside on cards, tape or disk.

The User Control Cards are required for each run of treatment. The cards must be submitted in the same order as they are described here. The file is assigned to FORTRAN Unit #9.

CARD #1

Type: Title Card
Purpose: Supply Descriptive Information for Printed Reports.
Number: 1 only
Format: Col. 1-80 - Comments to describe treatment run.

CARD #2

Type: Service Areas Card
Purpose: Allow variable number of sewage service areas, planning units and watersheds.
Number: 1 only
Format: Col. 1-2 - I2 - # of sewage service areas (max=50)
3 - Blank
4-5 - I2 - # of watersheds (max=99)
6 - Blank
7-8 - I2 - # of Planning Units (max=99)

Card #3

Type: FORTRAN Unit Assignment Card
Purpose: Assign FORTRAN unit numbers to input files.
Number: 1 only

Format: Col.

1 - I1 - '1' identification

2 - X - Blank

3-5 - I3 - FORTRAN unit number for service area data set

6-8 - I3 - FORTRAN Unit number for service area treatment efficiencies

9-11 - I3 - FORTRAN unit number for geographic descriptions

12-14 - I3 - FORTRAN unit number for sewered stormwater runoff file

15-17 - I3 - FORTRAN unit number for sewage file (input)

The SEWAGE program output file contains the average daily and maximum daily sewage flows and pollutant loads estimated to result from a particular level of water usage by the domestic and commercial sectors.

It is assigned the FORTRAN unit number codes on the unit assignment card. If this file is not selected for input, the number of planning units on the service areas card must be coded as zero.

The Sewered Stormwater Runoff File contains the flows and loads of runoff from the storm entering the sewage system. This file is output by the SPLIT program. As with the file above, the unit number is assigned on the Unit Assignment Card. The file can be bypassed if a zero is coded for the number of watersheds on the Service Areas File.

There are three user-created datasets which must be supplied to the TREATMENT program.

(a) The Sewer Service Area Assignments file assigns each watershed and each planning unit to a sewage service area.

(b) The Sewer Service Area Treatment Efficiencies file contains user-specified pollutant removal efficiencies that represent the actual or desired level of treatment in each sewage service area.

(c) The Geographic Unit Descriptions file provides for each sewage service area, watershed and planning unit a literal description of its physical location.

SEWAGE SERVICE AREA ASSIGNMENTS FILE

COL.	FORMAT	DATA
1-2	I2	Record Identification
3-5	I3	21 = Watershed No. 22 = Planning Unit No.
6-8	I3	Sewage Service Area Number
9-80	72X	Blank

Do not include assignments cards for an input file (wastewater or stormwater) that will be bypassed in the input operation.

SEWAGE SERVICE AREA TREATMENT EFFICIENCIES FILE

COL.	FORMAT	DATA
1	I1	Record Identification '3'
2	1X	Blank
3-5	I3	Sewage Service Area Number
6-10	5X	Blank
11-23	F13.3	Percent BOD Removed
24-36	F13.3	Percent Nitrogen Removed
37-49	F13.3	Percent Phosphorus Removed
50-80	31X	Blank

Percentages are coded in decimal form, i.e., 25.5 percent = 0.255. One record must be provided for each sewage service area.

GEOGRAPHIC UNIT DESCRIPTIONS FILE

COL.	FORMAT	DATA
1-2	I2	Card Type 41 = Watersheds 42 = Planning Units 43 = Service Areas
3-5	I3	Watershed, Planning Unit or Service Area Number
6-10	5X	Blank
11-50	10A4	Geographic Description of Unit Location
51-80	30X	Blank

Do not include unit descriptions for an input file (wastewater or stormwater) that will be bypassed in the input operation.

Output Description

The TREATMENT program produces one tape or disk file and printed reports of all input and output data.

The tape or disk file output by the TREATMENT program contains the combined treated flows and loads discharged by each sewage service area into the estuary. This file contains the combined effluent of the wastewater and/or stormwater components. Information is directed to the print file in both list and report formats. The User Control Cards and the user-supplied input data are listed, record by record, as they are input by TREATMENT. Additionally, the user-supplied input data is also displayed in report form.

Formated reports of input flows and loads from the wastewater and stormwater components are produced, as is the report of the combined treated flows and pollutant loads calculated by the program.

POTOMAC ESTUARY MODEL

PURPOSE

The estuary component of the Framework model chain is designed to model the hydraulics and quality constituents of the Potomac Estuary during dry weather and storm flow conditions. The estuary model, in its present form is a result of modifications and additions to the EPA steady state Dynamic Estuary Model.(19)

The estuary model utilizes a two-dimensional network of interconnecting junctions and channels shown in Figure 21. The first component, the hydrodynamic portion, models the tidal condition of the estuary while the second component develops time-dependent concentration profiles of five water quality constituents.

CHARACTERISTICS OF OPERATION

Language: FORTRAN IV (G Level)

Region: DYNHYD - 250K
DYNQUA - 210K

PROGRAM DESCRIPTION

The model operations, Figure 22, begins with a simulation of estuary hydraulics. After the first tidal cycle (25 hours) of computer modeling is complete, the hydraulic characteristics—head, velocity and flow, are approximately identical at the end of each tidal cycle under constant inflow and tidal conditions. This condition is "dynamic steady state" and at this time water quality modeling commences with or without storm inflows. Storm conditions can be modeled any time after dynamic steady state is achieved. At the end of the storm inflow period, modeling of hydraulics is continued until dynamic steady state is once again achieved.

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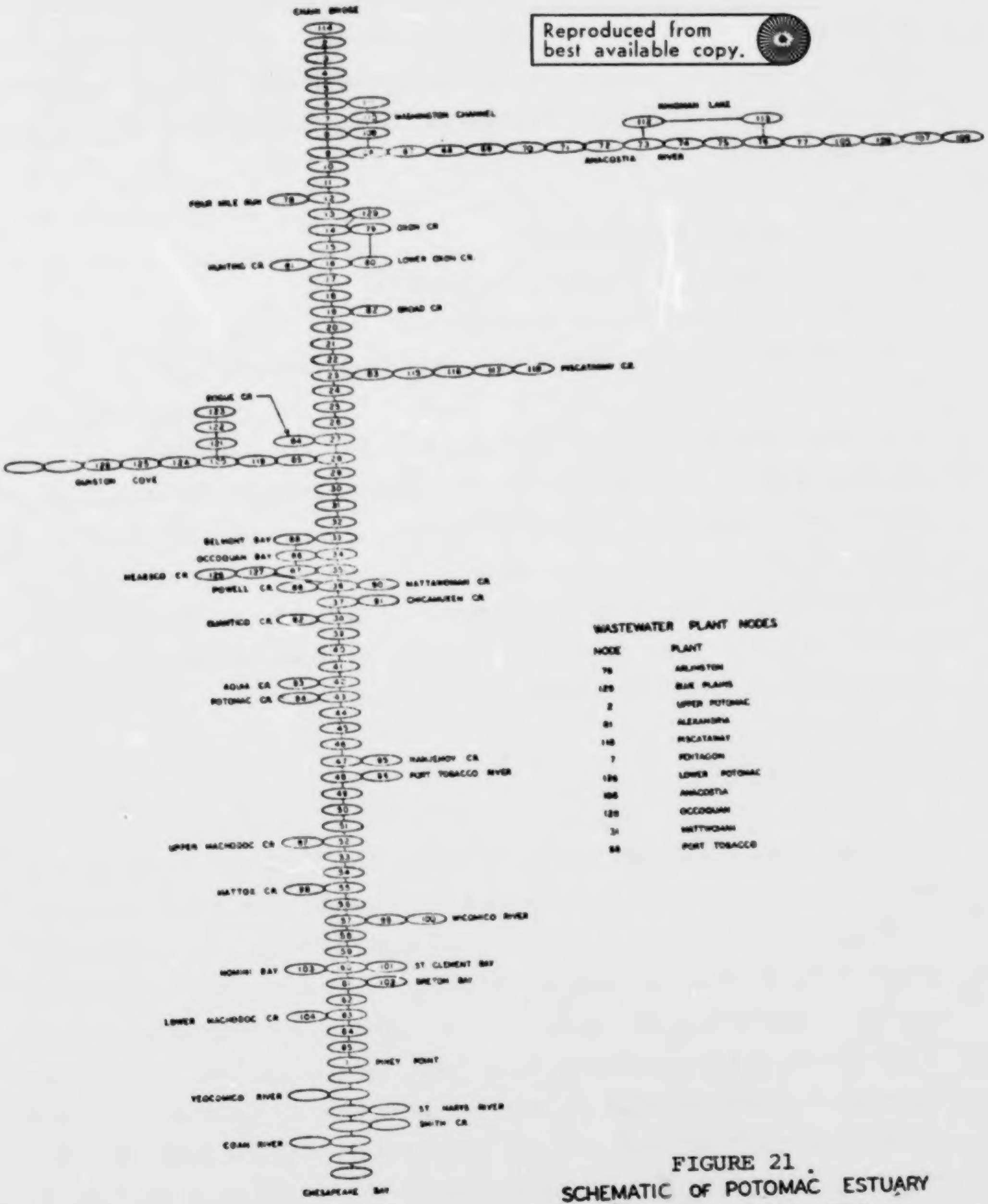
CHAIN BRIDGE
WASHINGTON CHANNEL
KINGMAN LAKE
ANACOSTIA RIVER
FOUR MILE RUN
OXON CR
HUNTING CR.
LOWER OXON CR.
BROAD CR
PISCATAWAY CR.
POHICK CR
GUNSTON COVE
BELMONT BAY
OCCOQUAN BAY
NEABSCO CR
POWELL CR.
MATTAWOMAN CR
CHICAMUXEN CR
QUANTICO CR.
AQUIA CR
POTOMAC CR.
NANJEMOY CR
PORT TOBACCO RIVER
UPPER MACHODOC CR
MATTOX CR.
WICOMICO RIVER
NOMINI BAY
ST CLEMENT BAY
BRETON BAY
LOWER MACHODOC CR
PINEY POINT
YEOCOMICO RIVER
ST. MARYS RIVER
SMITH CR.
COAN RIVER
CHESAPEAKE BAY

WASTEWATER PLANT NODES

NODE	PLANT
78	ARLINGTON
129	BLUE PLAINS
2	UPPER POTOMAC
81	ALEXANDRIA
118	PISCATAWAY
7	PENTAGON
126	LOWER POTOMAC
108	ANACOSTIA
128	OCCOQUAN
31	MATTAWOMAN
96	PORT TOBACCO

FIGURE 21 .
SCHEMATIC OF POTOMAC ESTUARY
FOR FWQA DYNAMIC MODEL

Hydraulic simulation must be continued for some time after storm inflow has ceased. Two points must be reached: first, the system will return to dynamic steady state; finally, one additional tidal cycle must be simulated for use by the quality program. Thus, three distinct parts of the hydraulics simulation are identified:

1. A start-up period;
2. The period of storm effect; and
3. One tidal cycle of dynamic steady state.

Only the last two are preserved for the quality simulation.

Water quality simulation begins after a dynamic steady state has been reached in the hydraulics solution. It continues through the storm inflow period, and, frequently, the user will wish to simulate water quality for many tidal cycles after storm inflow has ended because of the relatively slow response of this facet of the system. In figure 22, eight such tidal cycles are shown. The program is now able to repeat the dynamic steady state hydraulics for as many times as they are requested.

Hydrodynamic Model

The estuary is divided into 115 channels with 114 junctions, as shown in Figure 21. Each channel is assumed to be straight with a uniform cross-section and level bottom. Cross-sectional area, velocity, flow and head are determined, at each junction, every 90 seconds. Determination of these hydraulic characteristics is done in two steps, therefore two sets of equations are required. One set of equations determines head, velocity and cross-sectional area halfway through the 90-second time step and the other set determines these characteristics at the end of the time step. The first set of equations obtains rough approximations of the hydraulic characteristics which are then used to obtain more accurate estimates of the hydraulic characteristics at the end of the 90-second interval. These results in turn become the input for modeling hydraulic characteristics at the start of the next time increment at each junction.

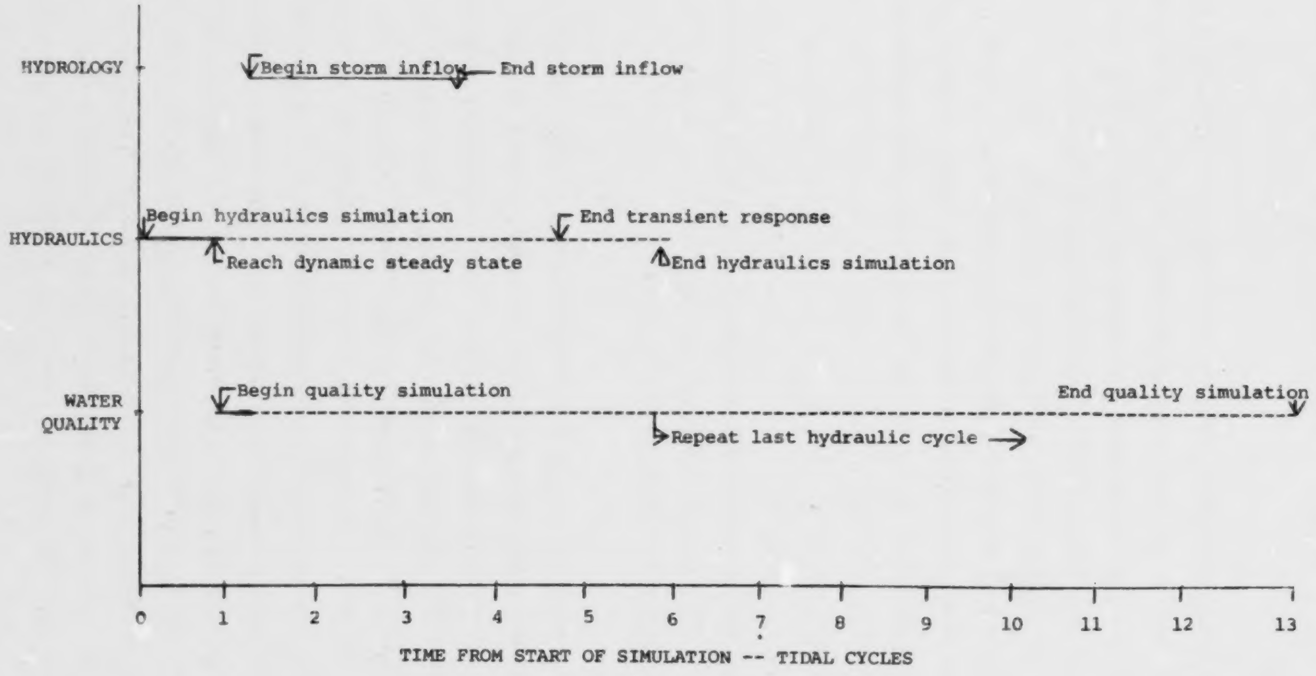
HYDROLOGY
Begin storm inflow
End storm inflow
HYDRAULICS
Begin hydraulics simulation
End transient response
Reach dynamic steady state
End hydraulics simulation
WATER QUALITY
Begin quality simulation
End quality simulation
Repeat last hydraulic cycle
0
1
2
3
4
5
6
7
8
9
10
11
12
13
TIME FROM START OF SIMULATION -- TIDAL CYCLES

FIGURE 22. MODEL OPERATIONS

Water Quality Model

The estuary quality model is used to calculate concentrations of five constituents in the Potomac Estuary. Concentrations are determined at each of the 114 junctions of the estuary every 30 minutes for five-day BOD, ammonia, nitrate, dissolved oxygen and chlorophyll A of photosynthetic phytoplankton.

For each 30-minute time interval, mass balance equations, which take into account chemical reactions undergone during the time step, are solved at each junction. The output concentrations of these parameters become the input, initial concentrations for modeling the next time increment. The model can be run for as many tidal cycles as desired. At the end of the storm inflow period, modeling of the quality condition is usually continued for a few more tidal cycles than the hydraulic modeling because changes in constituent concentrations is slower than in hydraulic characteristics.

Input Description

The model inputs are described in the data formats and specifications presented below. The model inputs can be classified in two main categories - data needs and system control requirements.

The data needs of the hydrodynamic model consist of point source inflows and withdrawals such as treatment plant discharges and channel characteristics at each estuary junction. Treatment plant discharges are determined with the assistance of the output from the TREATMENT program. The link between the sewage treatment data, developed by the TREATMENT program, is shown in Table 7. Channel characteristics including length, width, hydraulic radius, initial head and velocity have been developed based on field surveys. When simulating storm conditions, the model requires storm inflows specified according to the junction where it occurs and the times at which the storm begins and ends. This input is developed with assistance of the output from the runoff program. The link between the runoff program, is shown in Table 8. That table shows the estuary segments which receive the flow from the 65 watersheds modeled.

TABLE 7. LOCATION OF SEWAGE TREATMENT DISCHARGE POINTS IN THE POTOMAC ESTUARY

ESTUARY SEGMENT		SEWAGE TREATMENT AREA ACCORDING TO THE TREATMENT PROGRAM	
Number	Name	Number	Name
78	Washington Sailing Marina	2	Arlington County
13	Marbury Point	1	Virginia Upper Potomac
	" "	7	Upper Goose Creek and Loudoun County
	" "	9	Rock Creek & Upper Mont. Co.
	" "	8	Montgomery County Upper Potomac
	" "	10	Lower Montgomery County
	" "	11	Anacostia
	" "	14	Oxon Run
	" "	15	District of Columbia
81	Great Huntin Creek	3	Alexandria & Western Fairfax
83	Piscataway Bay	13	Lower Prince George's County
85	Gunston Cove	4	Southern Fairfax
87	Neabsco Creek	6	Eastern Prince William County

TABLE 8. LOCATION OF WATERSHED DISCHARGE POINTS IN THE POTOMAC ESTUARY

ESTUARY SEGMENT (Junction)		WATERSHED ACCORDING TO THE RUNOFF MODEL	
Number	Name	Number	Name
114	Chain Bridge	1-34	Potomac River Base Flow
2	Chain Bridge	35	Pimmit Run
5	Georgetown Channel	36,37	Rock Creek
6	Water Gate	38	Potomac Direct #6
72	Kingman Lane	39	Anacostia Direct, #1
108	Prince George's Marina	40-42	Anacostia-NW, NE & Paint Branch
12	Hunter Point	43	Fourmile Run
13	Oxon Run Confluence	44	Oxon Run
79	Goose Island	45	Cameron Run
16	Rosier Bluff	46	Potomac Direct #7
80	Fox Ferry	47	Belle Haven
81	Indian Queen Bluff	48	Broad Creek
82	Broad Creek	49	Potomac Direct #8
22	Hatton Point	50,51	Piscataway Creek
23	Fort Washington Marina	53	Potomac Direct #9
24	Bryan Point	52	Little Hunting Creek
25	Mount Vernon	54	Dogue Creek
84	Mount Vernon Yacht Club	55,56	Accotink & Pohick Creeks
29	Hallowing Point	57	High Point
31	Indian Head	60	Marumsco Creek
86	Freestone Point	58	Occoquan below the Dam
87	Occoquan Bay	59	Kane Creek
87	Occoquan Bay	61	Neabsco Creek
87	Occoquan Bay	62	Powell Creek
89	Cockpit Point	63	Quantico Creek
92	Quantico Creek	64	Little Creek
38	Possum Point	65	Chopawamsic Creek
39	Clifton Point		

The data needs of estuary quality programs consist of hydraulic characteristics developed in the hydrodynamic program, the chemical and physical characteristics of the constituents to be modeled, and initial constituent concentrations in each segment of the estuary. Much of the data has been collected through field surveys. During simulation of storm conditions, the concentrations of the constituents entering the estuary need to be specified.

The system control requirements for both models are similar in nature. These model inputs specify output formats and define the time step used in calculations as well as how many tidal cycles should be modeled. In addition, the hydrodynamics program has inputs which describe the system of interconnecting channels and junctions as well as the tidal condition. The estuary quality model also has inputs which define maximum allowable concentrations of constituents as well as constituent concentrations at the boundaries of the estuary.

Data formats and specifications for both the hydrodynamic and quality components follow below.

HYDRODYNAMIC SIMULATION PROGRAM (DYNHYD)

Data Formats and Specifications

In the following description defining the format of the input data deck required to execute program DYNHYD the symbol:

*	denotes that a series of cards as described may be required.
a	denotes that the card or series of cards may not be required.
R	indicates "right hand justified," i.e., any quantity so described must appear as far as possible to the right in its data field.
	indicates a decimal point must appear in the field.

The data needs of estuary quality programs consist of hydraulic characteristics developed in the hydrodynamic program, the chemical and physical characteristics of the constituents to be modeled, and initial constituent concentrations in each segment of the estuary. Much of the data has been collected through field surveys. During simulation of storm conditions, the concentrations of the constituents entering the estuary need to be specified.

The system control requirements for both models are similar in nature. These model inputs specify output formats and define the time step used in calculations as well as how many tidal cycles should be modeled. In addition, the hydrodynamics program has inputs which describe the system of interconnecting channels and junctions as well as the tidal condition. The estuary quality model also has inputs which define maximum allowable concentrations of constituents as well as constituent concentrations at the boundaries of the estuary.

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indicates a decimal point must appear in the field.

R. indicates that the value is right hand justified but may have a decimal point to override the programmed decimal point

. indicates the repetition of the format on the same card.

.... indicates the start of a new card.

Card	Column	Name	Description
1	1-80	ALPHA(I)	Alphanumeric identifier — printed as first line of output (up to 80 characters). I = 1,20 with A4 format.
2	1-80	ALPHA(I)	Alphanumeric identifier — printed as second line of output (up to 80 characters). I = 21,40 with A4 format.
3	1-5R	NJ	Total number of junctions in system.
	6-10R	NC	Total number of channels in system.
	11-15R	NCYC	Total number of time steps (cycles) to be completed.
	16-20R	NPRT	Number of time steps between printouts. Normally specified to give output at one-half or hourly frequencies.
	21-25R	NOPRT	Number of junctions for which output is printed.
	26-35R	DELT	Time interval, in seconds, used in solution.
	36-45R	TZERO	Time, in hours, at which computations begin. Allows starting point to be anywhere on tidal cycle.
	46-50R	NETFLW	Option parameter. If NETFLW is specified as any non-zero integer, Subroutine HYDEX is called to compute net flows and summarize hydraulic parameters. If NETFLW is specified as zero, Subroutine HYDEX is not called.
4	1-5R	IPRT	Printed output begins at this cycle number and at each NPRT cycle thereafter.

	6-10R	IWRTE	Hydraulic parameters are stored on magnetic tape or disk beginning at this cycle number.
	11-15R	KPNCHI	Punch interval for restarting. Magnetic tape is written at this cycle and at each KPNCHI cycle thereafter.
*5	1-5R	J	Junction number (read as dummy variable JJ to check card sequence).
	6-15R.	Y(J)	Initial head specified at junction J, in feet.
	16-25R.	AREAS(J)	Surface area of junction J, in square feet.
	26-35R.	QIN(J)	Specified inflow or withdrawal at junction J, in cfs. Inflows must be assigned negative values, withdrawals positive.
	36-40R	NCHAN(J,1)	Channel number of any one of the channels entering junction J.
	41-45R.	NCHAN(J,2)	Channel number of a second channel (if it exists) entering junction J. If only a single channel element enters the junction NCHAN(J,2) and the remaining NCHAN values must be assigned a zero value. If exactly two channels enter the junction NCHAN(J,3) and the remaining NCHAN values must be assigned a zero value, etc.

Card	Column	Name	Description
	56-60R	NCHAN(J,5)	Channel number of the fifth channel (if it exists) entering junction J. If less than five channels enter the junction (NCHAN(J,5) must be assigned a zero value.
	....	....	....
	Card 5 is repeated for each junction in the network (NJ cards).	....	....
*6	1-5R	N	Channel number (read as dummy variable NN to check card sequence).
	6-13R.	CLEN(N)	Length of channel N, in feet.
	14-21R.	B(N)	Width of channel N, in feet.
	22-29R.	AREA(N)	Initial cross-sectional area of channel N, in square feet. Must correspond to the initial heads specified at the junctions at the ends of the channel.
	30-37R.	R(N)	Hydraulic radius of channel N, in feet. Taken as the channel depth.
	38-45R.	CN(N)	Manning's roughness coefficient, dimensionless.
	46-53R.	V(N)	Initial mean velocity in channel N, in fps.
	54-58R	NJUNC(N,1)	The junction number at one end of channel N.

Card	Column	Name	Description
	59.63R	NJUNC(N,2)	The junction number at the other end of channel N.
	Card 6 is repeated in the network (NC cards).	....	....
*7	1-5R	JPRT(1)	Numbers of those junctions for which printout is desired. There will be NOPRT different junction numbers, fourteen to a card. The numbers need not be in sequence.
	6-10R	JPRT(2)	
	11-15R	JPRT(2)	
	.	.	
	.	.	
	.	.	
	.	.	
	....	....	Card 7 is repeated as many times as necessary to include all junction numbers for which printout is desired.
8	1-5R	NK	Number of coefficients used to specify the tidal input.
9	1-10R.	PERIOD	Period of the input tide, in hours.
	11-20R	A(1)	Coefficients for tidal input at specified junction(s). Obtained from regression analysis program, REGAN.
	11-30R.	A(2)	
	.	.	
	.	.	
	.	.	
	.	.	
	71-80R.	A(7)	
10	1-3R	NJSW	Number of junctions with hydrograph input.
*11	1-5R	JSW(1)	Junction number for first hydrograph.
	5-10R	JSW(2)	Junction number for second hydrograph.
	.	.	
	.	.	
	.	.	
	.	.	
	etc.	JSW(NJSW)	Junction number for last hydrograph (maximum 100).

Card	Column	Name	Description
12	1-10R.	TE	Time of following set of hydrograph points (seconds).
*13	1-10R.	QE(1)	Ordinate of first hydrograph at time TE (cfs).
	11-20R.	QE(2)	Ordinate of second hydrograph at time TE.
	.	.	
	.	.	
	.	.	
	.	.	
	etc.	QE(NJSW)	Ordinate of last hydrograph at time TE.
	Cards 12 and 13 will be repeated for each succeeding set of hydrograph points.		
14	1-5		99999 - this card signals the end of the last set of hydrographs.
15	1-80	ALPHA(I)	Alphanumeric identifier--printed as part of heading for printout resulting from HYDEX. I = 41,60 with A4 format.
16	1-80	ALPHA(I)	Alphanumeric identifier --printed as part of heading for printout resulting from HYDEX. I = 61,80 with A4 format.
17	1-5R	NODYN	Number of hydraulic time steps per quality time step. Defines the quality time step as the product of NODYN and DELT.
	6-10R	NPFACT	Number of tidal periods to be retained for water quality simulation.

NOTE: Cards 10, 11 and 12 are read by Subroutine HYDEX but immediately follow the previous data cards.

DYNAMIC WATER QUALITY PROGRAM (DYNQUA)

Data Formats and Specifications - June 1974

In the following description defining the format of the input data deck required to execute program DYNQUA the symbol:

*	denotes that a series of cards as described may be required.
a	denotes that the card or series of cards may not be required.
R	indicates "right hand justified," i.e., any quantity so described must appear as far as possible to the right of its data field.
.	indicates a decimal point must appear in the field.
R.	indicates that the value is right hand justified but may have a decimal point to override the programmed decimal point.
. . . .	indicates the continuation of the same format on a card.
....	Indicates the start of a new card.

Card	Column	Name	Description
1	1-5R	NJ	Total number of junctions in system. Identical to NH in program DYNHYD.
	6-10R	NC	Total number of channels in system. Identical to NC in Program DYNHYD.
	1-15R	NSTART	Cycle number from hydraulic solution which is the initial cycle on the hydraulic extract input tape 3. Identical to NSTART in DYNHYD (HYDEX).
	16-20R	NSTOP	Cycle number from hydraulic solution which is the final cycle on the hydraulic extract tape 3. Identical to NSTOP in Subroutine HYDEX.
	21-25R	NODYN	Number of hydraulic time steps per quality time step. Identical to NODYN in Subroutine HYDEX.

Card	Column	Name	Description
	26-30R	MSTART	Starting cycle (on tape 3) for repeating last segment of hydraulics.
2	Blank Card		This card contains variables no longer used in the program.
3	1-5R	NRSTRT	Cycle number on input tape 3 (hydraulic extract tape) at which quality run is to begin (NSTART $\leq$ NSTRT $\leq$ NSTOP).
	6-10R	INCYC	Initial quality cycle number. For first run of a series INCYC should equal 1. For continuation or restart runs INCYC should equal x+1 where x equals the number of cycles completed previously.
	11-15R	NQCYC	Total number of quality cycles to be completed. NQCYC must include all cycles previously completed, i.e., NQCYC equals INCYC plus the additional cycles to be completed in the current run.
	16-20R	KZOP	Control option for calling Subroutines ZONES. KZOP must equal 1 to call ZONES or 2 to bypass ZONES.
	21-25R	KDCOP	Control option for printout of depletion correction message. KDCOP must equal 1 for printout or 2 to delete printout of depletion correction message.
	26-30R	NTAG	Counter which is reset to zero at the completion of each full tidal cycle. NTAG varies between zero and NSPEC where NSPEC is the number of quality cycles per tidal cycle.
	31-40R.	CDIFFK	Constant for computing diffusion coefficient.

Card	Column	Name	Description
4	1-5R	IPRT	Initial print cycle (IPRT must be $\geq$ INCYC). Printout begins for the first time at cycle IPRT and continues for one full tidal cycle at intervals of NQPRT cycles (time steps).
	6-10R	NQPRT	Number of quality cycles (time steps) between printouts. NQPRT normally is such that printout is obtained at hourly or two-hour intervals.
	11-15R	NEXTPR	Quality cycle number at which printout begins for second time and continues at NQPRT intervals for a full tidal cycle.
	16-20R	INTBIG	Interval, in quality cycles (time steps), between the start of printouts over a full tidal cycle. NEXTPR is increased by INTBIG at the completion of each full tidal cycle of output.
	21-25R	IWRITE	Cycle number at which storage of quality data on tape or disk begins for the first time. Data for each time step over a full tidal cycle is passed to Subroutine Qualex.
	26-30R	NEXTWR	Cycle number at which storage of quality data on tape or disk begins for the second time.
	31-35R	IWRINT	Interval, in quality cycles (time steps), between the storage of data on tape or disk. NEXTWR is increased by IWRINT at the completion of storing data for a full tidal cycle. Quality summaries are obtained at IWRINT intervals.
5	1-80	ALPHA(I)	Alphanumeric identifier for quality run-- printed as heading for output (I=41,60 with A4 format).
6	1-80	ALPHA(I)	Alphanumeric identifier for quality run— printed as heading for output (I=61,80 with A4 format).

Card	Column	Name	Description
7	1-5R	NUMCON	Number of quality constituents considered in the $(1 \leq \text{NUMCON} \leq 5)$.
8	1-5R	NCONDK(1)	Number (1 through 5) of the first nonconservative constituent, e.g., if the first two constituents are conservative and the third nonconservative then NCONDK(1)=3. If none of the NUMCON constituents are treated as nonconservative NCONDK(1) must be set equal to zero.
	6-10R	NCONOX(1)	Number of the constituents which is associated with the nonconservative constituent (BOD) assigned to NCONDK(1). If dissolved oxygen is not being considered NCONOX(1) must be set equal to zero.
	Etc.		Maximum 5 constituents.
9	1-5	NR	The number of cards from which data on depth and photosynthesis, respiration and benthos rates are to be read.
10	1-10	NFJ(I)	The number of the first junction having the data found on this card.
	11-20	NLJ(I)	The number of the last junction having the data found on this card.
	21-30	PHOTT(I)	The photosynthetic rate between junctions NFJ(I) and NFL(I).
	31-40	RESS(I)	The respiration rate between junction NFJ(I) and NFL(I).
	41-50	DEPTHH(I)	The euphotic zone depth between junctions NFJ(I) and NFL(I).
	51-60	BENTT(I)	The benthos uptake rate between NFJ(I) and NFL(I).

Card	Column	Name	Description
*11			Cards 11 and 12 should be omitted if NCONDK(1)=0.
	1-10	DECAY(1)	Decay coefficient (base e, per day) applied to the nonconservative constituent assigned to NCONDK(1),i.e., to the first nonconservative constituent.
	11-20R	REOXK(1)	Reoxygenation coefficient (base e, per day) applied to the DO constituent (if any) assigned to NCONOX (1).
	21-30	-	Blank
	31-40R.	RORDER(1)	=1., use first order equation. =2., use second order equation.
	41-50R.	TEMP(1)	Temperature (base 20) for correction of rate constants.
	51-60R.	BACKC(1)	Background concentration for this constituent; computed value will not be less than BACKC.
	61-70R	IREOXK(1)	=1, Reoxygenation will occur for this constituent. =0, Reoxygenation will not occur for this constituent.
	71-80R.	THETA(1)	Water temperature (C).
	.		
	.		
	.		
	.		
	Etc.		Maximum 5 constituents.
*12	1-80	ALPHA(I)	Alphanumeric identifier, one card for each constituent (I=121, NALPHA where NALPHA = NUMCON*20).
13	1-10R.	CLIMIT(1)	Concentration limit for first constituent. Run is aborted is concentration exceeds CLIMIT.

Card	Column	Name	Description
	11-20R.	CLIMIT(2)	Concentration limit for second constituent.
	.	.	.
	.	.	.
	.	.	.
	.	.	.
	41-50R.	CLIMIT(5)	Concentration limit for fifth constituent.
14	1-5R	NUNITS	The number of units for which waste water return factors are applied. A unit consists of two junctions at which diversions occur and two junctions at which the waste water from those diversions is returned. The same factor is applied to both junctions in each pair. If NUNITS=0, cards 13 should be omitted.
15	1-3R	JDIV1(1)	The junction number of the first diversion in unit 1.
	4-7R	JDIV2(1)	The junction number of second diversion in unit 1.
	9-11R	JRET1(1)	The junction number of the first return flow in unit 1. JRET1(1) is paired with JDIV1(1).
	12-15R	JRET2(1)	The junction number of the second return flow in unit 1. JRET2(1) is paired with JDIV2(1).
	16-20R.	RETFAC(1,1)	Return factor for unit 1 and constituent 1.
	21-28R.	CONST(1,1)	Constant applied to junction in unit 1 for constituent 1.
	29-33R.	RETFAC(1,2)	Return factor for unit 1 and constituent 2.
	34-41R.	CONST(1,2)	Constant for unit 1 and constituent 2.
	.	.	.
	.	.	.
	.	.	.
	.	.	.

Card	Column	Name	Description
	68-72R.	RETFAC(1,5)	Return factor for unit 1 and constituent 5.
	73-80R.	CONST(1,5)	Constant for unit 1 and constituent 5.
	Etc.	....	NUITS times.
*16	1-5R	J	Junction number. Read as dummy variable JJ to check card sequence.
	6-15R.		Field not used.
	16-25R.	C(J,1)	Initial concentration assigned to junction J for the first constituent.
	26-35R.	CBASE(J,1)	The specified concentration of the first constituent in the base flow discharge QUINST(J) at junction J.
	36-45R.	C(J,2)	Initial concentration assigned to junction J for the second constituent (if more than one constituent is considered).
	46-55R.	CBASE(J,2)	The specified concentration of the second constituent in the base flow discharge QINST(J).
	Etc.		
17	1-5R.	NGROUP(1)	The number of groups (up to 10) of junction numbers for which it is desired to increment the initial concentrations of the first constituent which were previously read as input. There is no limit (up to NJ) to the number of junctions comprising a group but the numbers must be consecutive.
*18	1-5R.	FACTR(1,1)	Multiplication factor to be applied to the initial concentration of the first constituent at those junctions in the first group. This card will not be required if NGROUP(1)=0.
	6-10R	NJSTRT(1,1)	The first (lowest) junction number in the sequence of junctions comprising the first group for first constituent.

Card	Column	Name	Description
	11-15R	NJSTOP(1,1)	The final (highest) junction number in the sequence of junctions comprising the first group for the first constituent.
	Etc.		
19	1-5R	KNOP(1)	Control option for specifying concentration of first constituent at boundary. If boundary concentration is constant over full tidal cycle KBOP(1)=1, if variable over tidal cycle KBOP(1)=2.
	6-10R	KBOP(2)	Control option for specifying concentration of second constituent at boundary. KBOP(2)=1 for constant boundary, or 2 for variable boundary.
	Etc.		
20	1-5R	NSPEC	The number of quality time steps per tidal cycle.
21	1-10R.	CIN(1,1)	The boundary concentration specified for the first constituent for the initial time step. If KBOP(1)=1 then CIN(1,1) is the constant boundary concentration and no additional specification is required for the first constituent.
	11-20R.	CIN(1,2)	The boundary concentration specified for the first constituent for the second time step if KBOP(1)=2.
	. . . .	. . . .	. . . .
	61-70R	CIN(1,7)	The boundary concentration specified for the first constituent for the seventh time step.
	....	....	Card 21 is repeated as necessary to specify all NSPEC boundary concentrations for the first constituent.
	Etc.		

Card	Column	Name	Description
22	1-5R	NOPRT	The total number of junctions for which printout is desired.
*23	1-5R	JPRT(1)	Junction number for which printout is desired.
	6-10R	JPRT(2)	Junction number for which printout is desired.
	.	.	.
	.	.	.
	.	.	.
	.	.	.
	Etc.		
24	1-3R	NJSW	Number of junctions with pollutograph input.
25	1-5R	JSW(1)	Junction number for first pollutograph.
	6-10R	JSW(2)	Junction number for second pollutograph.
	.	.	.
	.	.	.
	.	.	.
	.	.	.
	Etc.	JSW(NJSW)	Junction number for last pollutograph (maximum 100).
26	1-10R.	TE	Time of following set of pollutograph points (hrs.).
27	1-10R.	CSPEC1	Ordinate of pollutograph for first constituent, first junction at time TE(mgl).
	11-20R.	CSPEC1	Ordinate of pollutograph for first constituent, second junction at time TE(mgl).
	.	.	.
	.	.	.
	.	.	.
	.	.	.
	Etc.	CSPEC1	Ordinate of pollutograph for first constituent, last junction at time TE(mgl).

Data Sources

The source of data for the estuary model has been a series of studies and reports done over the last 10 years.[21, 22, 23, 24, 25, and 26]

Theories and Algorithms

The estuary model is a real time system incorporating hydraulic and quality components. The hydraulic solution describes tidal movement, while the quality solution considers the basic transport mechanisms of advection and dispersion as well as the pertinent sources and sinks of each constituent. The estuary model can concurrently simulate five different constituents. They may be either conservative or nonconservative and may be interrelated in any mathematical linkage. A detailed description of the theory behind this model is available from EPA[19], while the sequence of calculations in the algorithm is presented below.

Estuary Hydrodynamic Model

A summary of the mathematical analyses and constants is presented in Appendix B. Equations 1 through 11 are solved, as used in the model, for each ninety-second time step for each junction of the estuary. The solutions of these equations for the first time step are used as input data for the subsequent time step. The equations are solved in two steps during the time step to aid in obtaining a stable solution and to shorten the number of time steps required to reach a steady state estuary flow condition; that is, until the start of the next tidal cycle at each junction are identical to the heads of the preceding tidal cycle at the corresponding junctions.

In the first half of the time step the "a" equations are solved (that is 1a , 2a , etc.) while in the second half of the time the "b" equations are solved. Essentially, the solutions of the "a" equations provide a rough approximation of the junction heads and channel velocities which are then used in the "b" equations to obtain more accurate estimates of the junction heads and channel velocities required for the Estuary Quality Model. Equations 12 and 13 are applied only in the latter half of the time step. A description of the solution of these equations for a pair of adjacent junctions and their channels is now discussed.

A friction coefficient using Eq. 2a is calculated by means of the Chezy-Manning relationship with a value for the hydraulic radius of the channel connecting the adjacent junctions calculated from Eq. 1a using the vertical cross-section of the channel at the start of the time step. Eq. 3a is used to calculate the change in head between adjacent junctions at the start of the time step. This result is used by Eq. 4a to determine the change in channel cross-section area connecting adjacent junctions at the start of the time step. A flow rate is calculated for each channel leaving the junction by Eq. 5a . Equation 6a is used to sum the net flows out of a junction including withdrawals for water supply and irrigation, water additions from streams tributary to the estuary and from waste treatment facility flows into the estuary and stormwater flows into the estuary during storms. Equation 7a then is used to calculate a new head for the junction as a result of these flows occurring during the first half of the time step.

Equation 7a together with the value of the head of a junction from the end of the previous time step, an average change in head along the channel between adjacent junctions for the first half of the time step, is calculated by Eq. 8a . This now enables Eq. 9a to calculate an average cross-section area of the channel for the middle of the time step. Using the channel cross-section area changes obtained from Eq. 4a and the junction head changes obtained from Eq. 8a , and Eq. 10a, one can calculate an average velocity gradient for the first half of the time step along a channel connecting adjacent junctions. This value of velocity gradient together with the channel friction coefficient of Eq. 2a, the value of channel velocity at the start of the time step, a channel head gradient obtained from Eq. 3a, and input data on the length of the channel, is used in Eq. 11a to determine channel velocity between adjacent junctions.

In a similar manner Eq. 1b through 11b are solved with one exception; at the most seaward junction the head at the end of the time step is calculated from given data representing the tidal boundary condition. At this junction Eq. 12 and 13 are used. The varying head operating at the seaward junction of the estuary provides the driving force seen at the remaining junctions of the estuary as a variation in water level.

Estuary Water Quality Model

The Estuary Quality Model is used to calculate the concentration of five constituents in the Potomac Estuary. For the 114 junctions of the Potomac Estuary concentrations are calculated each half hour. Thus for each tidal day, (25 hours), 28,500 concentrations are calculated. The five constituents are BOD dissolved oxygen, ammonia, nitrate, and chlorophyll A of photosynthetic phytoplankton.

The interaction of these constituents is shown in Figure 23, for one junction and one time step. The BOD_5 load in the junction reacts during the time step with the dissolved oxygen in the junction to result in the exertion of an ultimate carbonaceous oxygen demand. Similarly the ammonia (NH_3) load in the junction reacts during the time step with the dissolved oxygen in the junction to result in the exertion of an ultimate nitrogenous oxygen demand. The sum of the ultimate carbonaceous and nitrogenous oxygen demand are represented in the figure as ultimate O_2 demand.

The ammonia is oxidized in the estuary in a nitrification process to form nitrate. The chemical equations are shown in Appendix C, Eq. 14 . The nitrate is incorporated into photosynthetic phytoplankton in the proportion, 93 micrograms of chlorophyll A per milligram of nitrate as N.

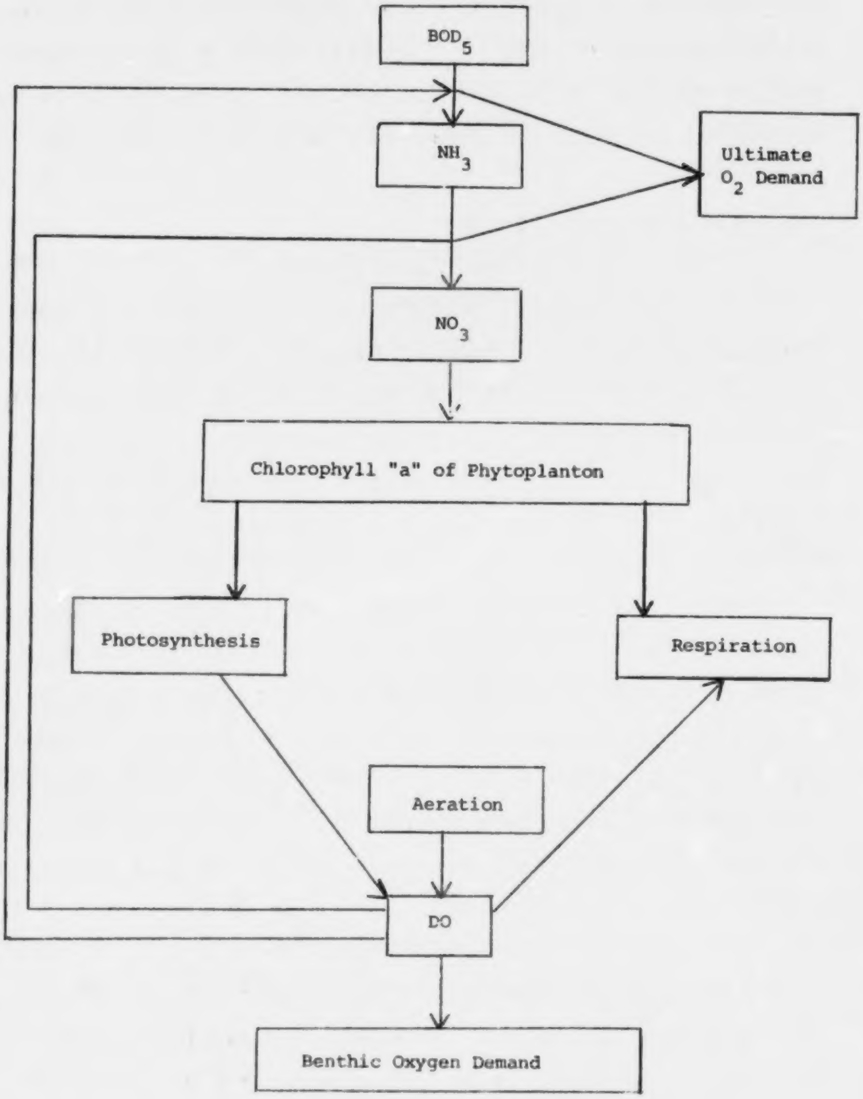
BOD5
NH3
Ultimate O2 Demand
NO3
Chlorophyll "a" of Phytoplanton
Photosynthesis
Respiration
Aeration
DO
Benthic Oxygen Demand

FIGURE 23. WATER QUALITY MODEL BASIS FOR COMPUTATIONS

The mass of chlorophyll A, which is a measure of the photosynthetic phytoplankton in the junction, adds dissolved oxygen through the process of photosynthesis to the junction at the rate of 0.012 milligrams of O_2 per hour per microgram of chlorophyll A. This reaction, however, takes place during daytime and only in the euphotic zone. The depth was set at two feet and the daytime portion of the diurnal cycle was set at 12 hours in the model for all junctions.

To account for respiration, the mass of chlorophyll A is used to remove dissolved oxygen from the junction at the rate of between 0.0006 and 0.0008 milligrams of O_2 per hour per microgram of chlorophyll A. This reaction takes place in the model throughout the diurnal cycle in the full depth of estuary for all junctions.

Oxygen is added through the air-water interface to the junction by aeration. This effect is modeled using the O'Connor-Dobbins multiple regression equation to calculate the reaeration coefficient. The reaeration coefficient equation is shown in Appendix C, as Eq. 12 . The amount of oxygen added by the model to the junction during the time step is proportional to the dissolved oxygen saturation deficit.

Dissolved oxygen is removed from the junction by the consumption of oxygen by the benthos based on a constant for all junctions of 1 gram of O_2 per square meter per day.

The interaction of the constituents take place at varying rates in first order reactions; the equation of which is shown in Appendix D, Eq. 21 . The values of the reaction rates are shown in the constants section of Appendix D. The half-life of ammonia in a junction due to its reaction with oxygen is 3.01 days. The half-life of BOD_5 due to its reaction with oxygen in a junction is 4.08 days. The half-life of chlorophyll A because of predation in the junction is 7.32 days. The half-life of nitrate in a junction due to uptake by photosynthetic phytoplankton is 7.69 days. All of these half-lives are based on a water temperature of 20 C; adjustment for water temperature other than 20 C is performed by Eq. 22 of Appendix D.

The concentrations of the five constituents are calculated for each thirty-minute time step in the Estuary Quality Model in a manner which is summarized in the thirty equations of Appendix D. These equations represent the calculations of the five constituents concentrations at one junction for one time step.

The concentration of each constituent in a junction for each time step is calculated by Eq. 1 based on the mass of the constituent in the junction and the volume of the junction at the end of the half-hour time step. The volume of the junction at the end of the time step is calculated by Eq. 2 using data from the Estuary Hydrodynamic Model. The mass of the constituent at the end of the time step is calculated for dissolved oxygen by Eq. 3 , for ammonia by Eq. 19, and for BOD_5 by Eq. 23 , for chlorophyll A by Eq. 27 , and for nitrate by Eq. 29 . These constituent masses in a junction at the end of the time step are based on physical, chemical, and biological processes in addition to being based on the initial mass of the constituent in the junction adjusted for an addition of mass from stormwater flows and treatment plant flows by Eq. 4 .

The physical processes primarily consist of the advection of the constituents in the direction of the flow simulated for each junction by the Estuary Hydrodynamic Model; and diffusion of the constituents toward the junction of lower constituent concentration. The mass of each constituent advected between adjacent junctions during a time step in the direction of flow is calculated by Eq. 5 utilizing the quarter-point concentration defined and calculated by Eq. 6 . The mass of each constituent transferred by diffusion between adjacent junctions during a time step in the direction from higher to lower concentration is calculated by Eq. 7 using a diffusion coeffient in the channel connecting the adjacent junctions calculated by Eq. 8 . Equation 8 , however, requires the calculation of hydraulic radius by application of Eq. 9 which is based on the results of the Estuary Hydrodynamic Model.

In addition to the advection and diffusion, a third physical process is simulated by the Estuary Quality Model, that is aeration or reaeration. The mass of molecular oxygen in a junction at the end of a time step, as previously mentioned, is calculated by Eq. 3 . One term of this equation represents the mass of molecular oxygen added to the junction by aeration during the time step. This term is calculated by Eq. 10 based on the dissolved oxygen saturation deficit at the start of the time step and the ratio of the mass of oxygen deficient in the junction at the start of the time step. This ratio is calculated by Eq. 11 based on a reaeration coefficient determined using the O'Connor-Dobbins relationship presented as Eq. 12 which is corrected for temperature by Eq. 13 .

The chemical and biological processes are reflected in the model as the remaining five terms of Eq. 3 . The first of these terms representing the mass of molecular oxygen removed from a junction, by reaction with ammonia, is calculated by Eq. 14 . This equation converts the mass of ammonia as N removed from the junction during the time step by reaction with molecular oxygen to the mass of molecular oxygen removed from the junction during the time step by reaction with ammonia as N. Eq. 20 is required to determine the mass of ammonia reacting with oxygen in the junction during the time step based on a decay rate calculated by Eq. 21 . Eq. 22 is also used to correct the decay rate constant for temperature. The decay constant is presented in the "CONSTANTS" section of Appendix D.

The second of the five chemical-biological terms of Eq. 3 represents the mass of molecular oxygen removed during the time step from the junction by reaction with ultimate biochemical oxygen demanding substances. Eq. 24 is used for this calculation based on the mass of five-day biochemical oxygen demand exerted during the time step calculated by Eq. 25 and converted to oxygen demanding substances on an ultimate basis by application of Eq. 26 and by application of the constant, R_3, which states that one milligram of dissolved oxygen is used in the reaction with one milligram of ultimate biochemical oxygen demanding substances. Equation 25 also requires the use of Eq. 21 to calculate the reaction rate between the oxygen demanding substances and the molecular oxygen in the junction.

The third and fourth of the five chemical-biological terms of Eq. 3 are used to represent the mass of molecular oxygen removed from the junction by respiration and added to the junction by photosynthesis during the time step. Eq. 15 is used to calculate the respiration term and Eq. 16 is used to calculate the photosynthesis terms. Both of these equations require an input representing the mass of chlorophyll A in the junction calculated by Eq. 27 at the end of the previous time step. Equation 27 is used to sum the terms changing the chlorophyll A levels of a junction from the start of a time step in the same manner that Eq. 3 sums the terms changing the dissolved oxygen level of a junction from the start of a time step. Thus Eq. 27 utilizes a term for chlorophyll A advection, calculated by Eq. 5 ; diffusion, calculated by Eq. 6 and 7 ; and decay, calculated by Eq. 28 . However, an additional term is used to represent the addition of Chlorophyll A which itself is proportional, in the model, to the concentration of photosynthetic phytoplankton. The relation between chlorophyll A and nitrate is shown in the "CONSTANTS" section of Appendix D. To solve the photosynthesis term of Eq. 3 by use of Eq. 16 also requires the solution of Eq. 17 to establish the volume of the euphotic zone.

The last term of Eq. 3 is used to represent the mass of molecular oxygen removed from the junction by reaction with the benthos of the junction during the time step. Eq. 18 is used to calculate this oxygen demand based on a benthic oxygen demand of 1 gram of molecular oxygen per square meter per day.

At this time Eq. 3 can be solved for the dissolved oxygen concentration in the junction at the end of the time step. Similarly, Eq. 19 can be solved for the ammonia concentration at the junction; Eq. 23 can be solved for the five day BOD concentration at simulation temperature; Eq. 27 can be solved for the chorophyll A concentration; and Eq. 29 can be solved for the nitrate concentration at the end of the time step.

These equations are solved for each junction and channel, until the concentration at each junction throughout one tidal cycle are repeated during the subsequent tidal cycle.

Model Outputs

Sample outputs for the components of the estuary model are found in Appendix C and D. In addition to what is presented in these appendices, much of the input data are printed out for informational purposes.

Estuary hydrodynamic model outputs include:

(a) Description of the hydraulic system in terms of head, velocity and flow every 90-seconds.
(b) Channel and junction physical characteristics.
(c) Maximum, minimum and average head and when it occurs.
(d) Tidal range in each junction.

Estuary water quality model outputs include:

(a) Description of hydraulic input, and mean tide.
(b) Concentrations of each water quality parameter at each junction every 30 minutes.
(c) Average, minimum and maximum concentration for each water quality parameter at each junction.
(d) All input data, coefficients and constants of all equations used in the model.

Model Availability

The most recent version of the Potomac Estuary Model may be obtained from the:

Annapolis Field Office
U.S.E.P.A. - Region III
Annapolis Science Center
Annapolis, Maryland 21801

REFERENCES

1. Spooner, C. S.; Graham, P. H.; Promise, J.; and Febiger, W. Technical Summary of the Framework Water Resources Planning Model. Washington, D.C.: Metropolitan Washington Council of Governments, 1974.

2. Metropolitan Washington Council of Governments, Report on the Use of Regional Plumbing Codes to Effect Water Conservation. Washington, D.C. June 1973.

3. U.S. Environmental Protection Agency. "State and Local Assistance - 40 CFR 35, Subpart E, Appendix A, Cost Effectiveness Analysis, Final Regulations." Federal Register. 39(29):5268-5270. February 11, 1974.

4. Spooner, Charles S.; Promise, John; and Graham, Philip H. A Demonstration of Areawide Water Resources Planning. Washington, D.C.: Metropolitan Washington Council of Governments, 1974.

5. Federal Water Pollution Control Acts of 1972. U.S. Code, Vol. 33 (1972).

6. Peat, Marwick, Mitchell, and Co. "Empiric" Activity Allocation Model: Application to the Washington Metropolitan Region. Washington, D.C.: Metropolitan Washington Council of Governments, 1972.

7. Hittman Associates, Inc. MAIN I, A System of Computerized Models for Calculating and Evaluating Municipal Water Requirements. Vol. I: Development of the MAIN I System Washington, D.C.: Office of Water Resources Research, U.S. Department of the Interior, 1968.

8. Hittman Associates, Inc. MAIN I, A System of Computerized Models for Calculating and Evaluating Municipal Water Requirements. Vol. II: Description of the MAIN I System and Library of Water Usage Parameters. Washington, D.C.: Office of Water Resources Research, U.S. Department of the Interior, 1968.

9. Hittman Associates, Inc. MAIN I, A System of Computerized Models for Calculating and Evaluating Municipal Water Requirements. Addendum to Final Report. Washington, D.C.: Office of Water Resources Research, U.S. Department of the Interior, 1969.

10. Hittman Associates, Inc. Forecasting Municipal Water Requirements. Vol. I: The MAIN II System. Washington, D.C.: Office of Water Resources Research, U.S. Department of the Interior, 1969.

11. Howe, Charles W., and Linaweaver, F. P. Jr. The Impact of Price on Residential Water Demand and its Relation to System Design and Price Structure. Washington, D.C.: Resources for the Future, Inc., 1967.

12. Howe, Charles W., et. al. Future Water Demands -- The Impacts of Technological Change, Public Policies, and Changing Market Conditions on Water Use Patterns of Selected Sectors of the United States Economy: 1970-1990. Washington, D.C.: Resources for the Future, Inc., 1971

13. Linaweaver, F. P. Residential Water Use. Report II: Phase Two. Department of Sanitary Engineering and Water Resources, the Johns Hopkins University. Washington, D.C.: Federal Housing Administration, 1965.

14. Linaweaver, F. P. Residential Water Use. Report I: Phase Two. Department of Sanitary Engineering and Water Resources, the Johns Hopkins University. Washington, D.C.: Federal Housing Administration, 1964.

15. Washington Suburban Sanitary Commission. Water and Sewer Rates. Hyattsville, Maryland, 1971.

16. Wolff, Jerome B.; Linaweaver, F. P.; and Geyer, John C. Commercial Water Use. Department of Environmental Engineering Science, the Johns Hopkins University. Baltimore County, Maryland: Baltimore County Department of Public Works, 1966.

17. Graham, P.; Costello, L.; and Matton, . "Estimation of Imperviousness and Specific Curb Length for Forecasting Stormwater Quality and Quantity." Journal of Water Pollution Control Federation, (April 1974),

18. Metcalf and Eddy. Stormwater Management Model, Final Report. Washington, D.C.: Environmental Protection Agency, 1971.

19. Feigner, K. and Harris, Howard S. Documentation Report, Federal Water Quality Administration Dynamic Estuary Model. Washington, D.C.: Federal Water Quality Administration, U.S. Department of the Interior, 1970.

20. Hittman Associates, Inc. Forecasting Municipal Water Requirements. Vol. II: The Main II System Users Manual. Washington, D.C.: Office of Water Resources Research, U.S. Department of the Interior, 1969.

21. Clark, L. J. and Kenneth D. Feigner, "Mathematical Model Studies of Water Quality in the Potomac Estuary," Annapolis Field Office, Region III, EPA, March 1972.

22. Jaworski, N. A.; Clark, L. J.; and Feigner, L. P. A Water Resource-Water Supply Study of the Potomac Estuary. Washington, D.C.: Chesapeake Technical Support Laboratory, U.S. Environmental Protection Agency, Region III, 1971.

23. Jaworski, N. A. and Clark, L. J. Physical Data Potomac River Tidal System Including Mathematical Model Segmentation. Washington, D.C.: Chesapeake Technical Support Laboratory, U.S. Environmental Protection Agency, 1970.

24. Chesapeake Technical Support Laboratory. Water Quality Survey of the Potomac Estuary -- 1965-1966 Data Report. U.S. Environmental Protection Agency, N.D.

25. Chesapeake Technical Support Laboratory. Water Quality Survey of the Potomac Estuary -- 1967 Data Report. U.S. Environmental Protection Agency, N.D.

26. Chesapeake Technical Support Laboratory. Water Quality Survey of the Potomac Estuary -- 1968 Data Report. U.S. Environmental Protection Agency, N.D.

27. Jaworski, N. A. and Clark, L. J. Nutrient Transport and Dissolved Oxygen Budget Studies in the Potomac Estuary: Technical Report 37, U.S. Environmental Protection Agency.

28. Lothrop, George T. and Hamburg, John R. "An Opportunity Accessibility Model for Allocating Regional Growth." Journal of the American Institute of Planners (May 1965), pp. 95-103.

29. Dickey, John W.; Leone, Phillip A.; and Scharte, Allan R. "Use of TOPAZ for Generating Alternate Land Use Schemes." Highway Research Record. Number 422, (1973), pp. 39-53.

30. Goldner, William, Projective Land Use Model (PLUM): A Model for the Spatial Allocation of Activities and Land Uses in a Metropolitan Region. BATSC Technical Report 219. Berkeley: Bay Area Transportation Study Commission, 1968.

31. Comprehensive Planning Organization. Interactive Population Employment Forecasting Model, Technical Users' Manual. San Diego, California, 1974.

32. Water Resources Engineers. Modifications to the Potomac Estuary Model. Springfield, Virginia: 1974.

23. Jaworski, N. A. and Clark, L. J. Physical Data Potomac River Tidal System Including Mathematical Model Segmentation. Washington, D.C.: Chesapeake Technical Support Laboratory, U.S. Environmental Protection Agency, 1970.

24. Chesapeake Technical Support Laboratory. Water Quality Survey of the Potomac Estuary -- 1965-1966 Data Report. U.S. Environmental Protection Agency, N.D.

25. Chesapeake Technical Support Laboratory. Water Quality Survey of the Potomac Estuary -- 1967 Data Report. U.S. Environmental Protection Agency, N.D.

26. Chesapeake Technical Support Laboratory. Water Quality Survey of the Potomac Estuary -- 1968 Data Report. U.S. Environmental Protection Agency, N.D.

27. Jaworski, N. A. and Clark, L. J. Nutrient Transport and Dissolved Oxygen Budget Studies in the Potomac Estuary: Technical Report 37, U.S. Environmental Protection Agency.

28. Lothrop, George T. and Hamburg, John R. "An Opportunity Accessibility Model for Allocating Regional Growth." Journal of the American Institute of Planners (May 1965), pp. 95-103.

29. Dickey, John W.; Leone, Phillip A.; and Scharte, Allan R. "Use of TOPAZ for Generating Alternate Land Use Schemes." Highway Research Record. Number 422, (1973), pp. 39-53.

30. Goldner, William, Projective Land Use Model (PLUM): A Model for the Spatial Allocation of Activities and Land Uses in a Metropolitan Region. BATSC Technical Report 219. Berkeley: Bay Area Transportation Study Commission, 1968.

31. Comprehensive Planning Organization. Interactive Population Employment Forecasting Model, Technical Users' Manual. San Diego, California, 1974.

32. Water Resources Engineers. Modifications to the Potomac Estuary Model. Springfield, Virginia: 1974.

APPENDIX A

ALTERNATE MODELS FOR COMMUNITY DEVELOPMENT COMPONENT

Urban land use and community development models have received much attention in the literature and in practical application in recent years. These computer simulation models offer data processing and empirical testing capabilities to evaluate theories regarding the location of activities in a region. The models considered in this paper are, in general, economic and/or population allocation models.

The Opportunity-Accessibility model was developed by Lothrop and Hamburg[28]. This is a model of urban growth which relies heavily on transportation concepts and makes use of a modification of Morton Schneider's intervening opportunity model.

Topaz, a technique for the optimum placement of activities in zones, was developed for use in Melbourne, Australia by Brotchie, Toakley, and Sharpe. An application to Blacksburg, Virginia by Dickey, Leone and Schwarte[29] is considered here.

Plum, the projective land use model, was developed by Goldner[36], and has been applied to studies in San Francisco 1968, San Diego 1972, and is currently being used in Baltimore. Plum is a successor to the Lowry Model, developed by Ira Lowry for the Rand Corporation in 1964.

IPEF73 Interactive Population Employment Forecasting Model[31] was developed by the Comprehensive Planning Organization of the San Diego Region although it has been used by a number of agencies in other areas of the Country.

OPPORTUNITY ACCESSIBILITY MODEL [28]

The purpose of the model is to allocate future estimates of activities (trip distributions) to small geographic areas, and forecast future distribution of people and trip making. Essentially, opportunities accessibility involves two concepts. One, asserts that the tripmaker will have alternatives for satisfying his trip purpose. The second, asserts that there is a finite probability that the tripmaker will stop at any of the alternatvies. This probability increases at each successfully encountered alternative, with each prior alternative not taken.

The model requires a measure of opportunities in each zone, and a measure of zone to zone travel time which serves as a basis for ranking zones. The probability of a trip terminating in any zone can then be calculated.

The model can be used to examine regional growth that might result from certain policies with respect to land development. For example, given a prescribed density, the model could be used to examine development that might occur.

$$Aj = A(e^{1o} - e^{-1(o+oj)})$$

Where:

Aj = the amount of activity to be allocated to zone j

A = the aggregate amount of activity to be allocated.

1 = probability of a unit of activity being sited at a given opportunity.

o = the opportunities for siting a limit of activity rank ordered by access value and preceding zone j.

oj = the opportunities in zone j.

Criteria for Model Design

1. The model based on a theoretical statement of the mechanisms of land development. Although it need not simulate individual decisions within the land market, it should give results which correspond to the real world.

2. The model should be incremental and recursive. Ideally, data on past land use and transportation systems should be used to simulate the present development pattern. If this ability is lacking increments of growth should be layered on the present structure.

3. The model should be relatively simple. A finite number of land uses and a minimum number of sub-sets of households should be required to minimize the difficulties of data acquisition and handling.

4. Ideally, the calculation of activity density should be contained within the model. Alternately, the model should readily accept exogenous densities.

5. The model should accept alternatives measures or indices of access. This condition provides the flexibility required for situations in which one measure is particularly appropriate to a given activity type with a different measure of access. This condition provides the flexibility required for situations in which one measure is particularly appropriate to a given activity type while a different measure of access is best suited to other activity types.

6. The model should be able to accept data from redevelopment, urban renewal, or new-town plans. This operation can be handled as a preliminary updating (internal to the model) of the land use and activity base or it can be done within the main frame of the model.

7. The model should be capable of being claibrated. For example, it should be possible to simulate past growth, or at least to calibrate the model parameters using the present structure.

8. Provision for sensitivity analysis should be considered in the design of the model. It is vital to be able to evaluate the effect of unit changes in a given parameter on all facets of the allocation produced by the model.

9. The output of the model should permit easy and rapid comprehension of allocation results, with particular emphasis on a simple graphic description of settlement patterns. This graphic output is particularly important for the comprehension and evaluation of alternative model inputs. Tabular outputs which can be used in calibration, sensitivity analysis, and allocation evaluation are also an obvious requirement.

10. Output from the model should be directly usable in existing traffic assignment procedures to minimize the difficulty and time involved in applying the results of the operation of the model.

TOPAZ[29]

Technique for Optimum Placement of Activities in Zones

Initially developed for use in Melbourne, Australia. The intent is to use a gravity model to generate land use allocation schemes that are optimal according to a set of objectives.

Capitol costs for water, sewerage, local streets, electricity, and individual building units are compiled for each zone and used in conjunction with travel costs and land use information to devise overall cost minus benefit values for the schemes.

A prediction was made of how much capital costs would be needed by 1985 for high and low density residential land and industrial land. Topaz was then used to allocate the needed land use areas so as to minimize public services and travel costs. Solutions were constrained so that areas would not be developed over their capacity.

The objective of Topaz is to minimize the combination of overall travel costs and capital costs minus benefits. Travel between zones and travel costs are determined with a gravity model. Capital costs and benefits are input values. The formulation of Topaz can be presented as follows:

$$MINZ = \underset{i}{E}\ \underset{j}{E}\ Cij\ Xij + \underset{j}{E}\ \underset{k}{Kjk}\ \underset{L}{E}\ PRi(Xij + Eij)\frac{EATi(Xik + Eik)\ \frac{1}{Tjk^2}}{E\ EATi(Xin+Ein)\ \frac{1}{Tjk^2}}$$

$$EXij = Ai, \text{ All } i$$

$$EXij = Bj, \text{ Allj}$$

$$EAi = EBj$$

Topaz has been found to have an extremely fast computation time. For a problem with 976 variables computing times on the IBM 360/65 Computer were about 1 minute.

The notation used is as follows:

Xij = amount of activity i allocated to zone j, acres;
Eij = existing amount of activity i in zone j, acres;
Ai = future amount of activity i to be allocated, acres;
Bj = area available for development in zone j, acres;
Csij = unit establishments benefits or capital costs for services for activity i in zone j, dollars/acre;
Cij = total establishment costs-benefits for locating activity i in zone j, dollars/acre;
PRi = daily vehicular trip production rate for activity i, vehicles/day/acre;
ATi = daily vehicular trip attraction ratefor activity i, vehicles/day/acre;
S2 = speed over link l, mph;;
L2 = length of link l, miles;
Pjk = set of links on the minimum time path from zone j to k;
Tjk = minimum highway travel time from zone j to k, min;
Mjk = distance over minimum highway travel time path from zone j to k, miles;
d = number of repetitions of daily trips in a year;
y = length of planning horizon, years;
pm_2 = vehicular cost to travel over link l, dollars/mile;
z = sum total of all travel costs and establishment cost-benefits, dollars;
z = value of the objective function of the linear "transportation problem," dollars; and
Kjk = cost over the planning period for a repetitive trip from zone j to k, dollars/daily trip.

PLUM

Projection Land Use Model[30]

A successor to the Lowry Model. It was implemented to provide the land use allocations and small zone forecasts of population, dwelling units, and employment.

The model is concerned with a set of tripmakers and their work to home or home to work tripmaking behavior.

Given a particular origin the model is used to show that the trips to any given destination will be proportional to the difficulty of reaching the destination and the degree to which that particular destination is capable of satisfying the trip purpose. The difficulty of reaching the destination is expressed in terms of travel time or cost. The attractiveness or opportunities located at a destination is used to measure the degree to which a particular destination can satisfy the trip purpose.

The allocation function has two components. The first component is the probability of making a trip of a particular length for a given purpose. The second component is the measure of attractiveness of the destination.

The probability of making a trip of length T is inversely proportional to an exponential function of the negative reciprocal of the length. This function is applied in the allocation of residences to concentric rings around each given origin zone. The probability of making a trip is calculated, then divided among the zones.

Based on this procedure, a matrix of trip probabilities for each zone to each other zone is calculated. With the use of a scale factor these probabilities are applied to the zonal employment to produce the distribution of residences.

To run PLUM, with a zone size up to about 350, a 360 model 40 or better with 256K bytes of storage is necessary. A small zone system could be run on a 128K byte machine with some reprogramming and overlays, however, only the layer computers have been used.

IPEF73 INTERACTIVE POPULATION EMPLOYMENT FORECASTING MODEL[31]

The IPEF73 model is designed to produce medium to long-term demographic and employment forecasts for an economic region. A central feature of the model is the assumption that employment opportunities play a significant role in determining net migration into or out of the region. As a result of this assumption, the model is best suited for use in regions where the number of workers commuting into or out of the region to jobs is not a significant factor. Such areas would include certain counties, most Standard Metropolitan Statistical areas and most states. In areas where interregional commuting is numerically important, it must be accounted for outside the IPEF73 model structure.

The model is a synthesis of two widely used techniques: the cohort-survival method of population forecasting and econometric approach to employment forecasting. In most previous applications these techniques have been used independent of each other, with the cohort-survival method considering such factors as birth rates, death rates and historical migration patterns, and the econometric model deriving forecasts from past trends, national and state growth patterns, and interindustry relationships. Conceptually, employing these two techniques independently suffers the shortcoming of ignoring the interdependence of demographic and economic forces. In fact, when these techniques have been used independently, it has been necessary at times to subject the forecasts to a reconciliation process to insure compatibility between population and employment. In the IPEF73 model the cohort-survival and economic techniques are combined so that the linkages between the demographic and economic sectors are explicit.

The economic sector is divided into two components: basic and local-serving. The "basic" component sells its products outside the local economy and is assumed to be a function of the region's comparative economic advantage (as reflected in historical trends) and the growth of external (i.e. national) markets, and is, therefore, independent of both the local-serving component of the economic sector and the demographic sector. The local-serving component, which primarily serves the local population, is assumed to respond to changes in both the basic economic sector (as changes in basic employment alter the demand for business-serving activities) and the demographic sector (as changes in population alter the demand for household-serving activities).

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[31] Comprehensive Planning Organization, Interactive Population Employment Forecasting Model, Technical Users' Manual (San Diego, California, 1974) p.__.

The demographic sector can also be divided into two components: an "autonomous" component consisting of births, deaths, retirement migration, and military migration, and a "dependent" component consisting of births, deaths, retirement migration, and military migration, and a "dependent" component consisting of employment-related migration. Births and deaths are calculated by applying age-specific fertility and survival rates to the base period population. Retirement and military migration are determined outside the model framework and are supplied as inputs to the model. The employment-related migration component is a function of changes in total employment which, in turn, is the sum of changes in basic and local-serving employment.

The IPEF73 model produces, for alternative assumed conditions and policies, demographic and economic forecasts at five-year intervals. The specific outputs of the model include:

1. Total, household and group quarters population by age, race and sex;
2. Labor force by age, race and sex;
3. School enrollment for five grade levels, by age, race and sex;
4. Households by age, race and sex of head;
5. Employment by industry.

Since the future values of the factors producing population and employment changes (i.e. the model inputs) can only be guessed at in most cases, it is often desirable to produce a range of forecasts reflecting the reasonable range of forecasts reflecting the reasonable range of the inputs.

As a result, a primary objective in developing the model was to produce a technique that would generate alternative forecasts in response to varying assumptions.

Perhaps more useful, especially to the decision-maker, is using the model to simulate the impact of alternative policy decisions on population and employment growth. Some examples of policies that could be studied are:

1. Increase in Family Planning Facilities - simulated by reducing birth rates;
2. Change to a Professional Military - simulated by changing the size and age structure of the military population and the number and age structure of military dependents;
3. Increase in Work Training Programs - simulated by increasing labor force participation rates and reducing the unemployment rate;
4. Restrictions on Industrial Growth - simulated by reducing the growth curves for basic employment;
5. Promoting Retirement Communities - simulated by increasing retirement-related migration.

APPENDIX B

Table B-1

EMPDA FILE FORMATS

Field #	Characters			Code	
	1st	Last	# of	PBZA	Field Description
	1	3	3	z	Policy Analysis District Number
DATA	5	4	1	z	Forecast Year
I.D.	7	8	2	z	Data Set# - To Ident. Spec. Alternatives Tested
	9	9	1	z	Run #
	10	10	1	A	Step Code - Identifies Data Stage in the Chained Process
	11	13	3	z	PAD Sequence Number
	14	16	3	z	Superdistrict Number
	17	18	2	z	Area Code: Col 17=0 - Inside Cordon = 1 Outside Cordon Col 18=0 - D.C. 1-Md. 2-Va.
Variable #					
	19	21	3	z	EPA Areas
	22	24	3		
1	25	32	8	z	# Families in Lower Income Quartile
2	33	40	8	z	# Families in Low/Middle Quartile
3	41	48	8	z	# Families in Upper/Middle Quartile
4	49	56	8	z	# Families in Upper Quartile
5	57	64	8	z	# URI HH's
6	65	72	8	z	# Employees in Manu/T.C.U.
7	73	80	8	z	# Employees in Retail/Wh. Trade
8	81	88	8	z	# Employees in F.I.R.E./Services
9	89	96	9	z	# Employees in Government
10	97	104	8	z	# Employees in Agriculture/Construction

APPENDIX B

Table B-1
(Continued)

EMPDA FILE FORMATS

Field #	Characters			Code	
	Ist	Last	# of	PBZA	Field Description
11	105	112	8	z	Acres of Residential Land
12	113	120	8	z	Acres of Industrial Land
13	121	128	8	z	Acres of Commercial Land
14	129	136	8	z	Acres of Intensive Institutional Land
15	137	144	8	z	Acres of Parks/Rec. Land
16	145	152	8	z	Acres of Vacant/Ag Land
17	153	160	8	z	Acres of Residual Land (R/W-Streets)
18	161	168	8	z	Acres of Land Sewered
19	169	176	8	z	Acres of Land Watered
20	177	184	8	z	# HH of Size 1
21	185	192	8	z	# HH of Size 2
22	193	200	8	z	# HH of Size 3
23	201	208	8	z	# HH of Size 4
24	209	216	8	z	# HH of Size 5
25	217	224	8	z	#HH of Size 6 and Over
26	225	232	8	z	# of White HH
27	233	240	8	z	# of Non-White HH
28	241	248	8	z	Population 5 years
29	249	256	8	z	Population 5 - 14 years
30	257	264	8	z	Population 15-19 years
31	265	272	8	z	Population 20 - 29 years
32	273	280	8	z	Population 30 - 49 years
33	281	288	8	z	Population 50 - 64 years
34	289	296	8	z	Population 65 years + over
35	297	304	8	z	#Employees on Commercial Land
36	305	312	8	z	# Employees on Industrial Land
37	313	320	8	z	# Employees on Intensive Inst. Land
38	321	328	8	z	# Employees on Other Land

APPENDIX B

Table B-1

EMPDA FILE FORMATS

Field #	Characters			Code	
	1st	Last	# of	PBZA	Field Description
39	329	336	8	z	# of Single Family HH
40	337	344	8	z	# of Multi Family HH
41	345	352	8	z	# of HH with 0 workers
42	353	360	8	z	# of HH with 1 worker
43	361	368	8	z	# of HH with 2+ workers
44	369	376	8	z	Acres of Extensive Institutional Land
45	377	384	8	z	Group Quarters Population
60	497	504	8	z	Metro Av. - V40*100/V69
61	505	512	8	z	Metro Av. - V15*100/(V11 V14)
62	513	520	8	z	Median Income Code .5 - 3.5
63	521	528	8	z	Gross HH's/Acre-V69/V97
64	529	536	8	z	Net HH's/Res Acre-V69/V11
65	537	544	8	z	Net Emp. Den-V92/(V12+V13+V14)
66	545	552	8	z	Used Land/(Used+Vac) (V11 V14) *100)/ (V11 V14)+V16)
67	553	560	8	z	Used Land/Total Land (V11 V14)*100)/V5
68	561	568	8	z	Activity Density - (V69+V92)/V97
69	569	576	8	z	Total Number of HH's (V1 V5)
70	577	584	8	z	Option 1 - Access X XX.XX Implied Deo
71	585	592	8	z	Option 2
72	593	600	8	z	Option 3
73	601	608	8	z	Option 4
74	609	616	8	z	Option 5
75	617	624	8	z	Option 6
76	625	632	8	z	Option 7 Data = % of Regional
77	633	640	8	z	Option 8 Variable V Reached Within
78	641	648	8	z	Option 9 X Minutes Via Mode Y Where
79	649	656	8	z	Option 10 Y = Skim Tree Table
80	657	664	8	z	Option 11
81	665	672	8	z	Option 12
82	673	680	8	z	Option 13

APPENDIX B

Table B-1

(Continued)

EMPDA FILE FORMATS

Field #	Characters			Code	
	1st	Last	# of	PBZA	Field Description
83	681	688	8	z	Option 14
84	689	696	8	z	Option 15
85	697	704	8	z	Total Trips From Home
86	705	712	8	z	Total Trips From Non-Home
87	713	720	8	z	# HH With 0 Autos
88	721	728	8	z	# HH With 1 Auto
89	729	736	8	z	# HH With 2 Autos
90	737	744	8	z	# HH With More Than 2 Autos
91	745	752	8	z	Total Labor Force
92	753	760	8	z	Total Employment
93	761	768	8	z	Total Population
94	769	776	8	z	$ - Low/Low-Mid Boundary
95	777	784	8	z	$ - Low-Mid/Upper-Mid Boundary
96	785	792	8	z	$ - Upper-Mid/High Boundary
97	793	800	8	z	Total Land Area

TABLE B-2

EMPIRIC MODEL OUTPUT FILE FORMAT

Field #	Characters			Code	
	1st	Last	# of	PBZA	Field Description
	1	3	3	z	Policy Analysis District Number
DATA	5	4	1	z	Forecast Year
I.D.	7	8	2	z	Data Set# - To Ident. Spec. Alternatives Tested
					Area Systems Descriptions
1	25	32	8	z	# Families in Lower Income Quartile
2	33	40	8	z	# Families in Low/Middle Quartile
3	41	48	8	z	# Families in Upper/Middle Quartile
4	49	56	8	z	# Families in Upper Quartile
5	57	64	8	z	# URI HH's
6	65	72	8	z	# Employees in Manu/T.C.U.
7	73	80	8	z	# Employees in Retail/Wh. Trade
8	81	88	8	z	# Employees in F.I.R.E./Services
9	89	96	9	z	# Employees in Government
10	97	104	8	z	# Employees in Agriculture/Construction

TABLE B-2

EMPIRIC MODEL OUTPUT FILE FORMAT

Field #	Characters			Code	
	1st	Last	# of	PBZA	Field Description
11	105	112	8	z	Acres of Residential Land
12	113	120	8	z	Acres of Industrial Land
13	121	128	8	z	Acres of Commercial Land
14	129	136	8	z	Acres of Intensive Institutional Land
15	137	144	8	z	Acres of Parks/Rec. Land
16	145	152	8	z	Acres of Vacant/Ag Land
17	153	160	8	z	Acres of Residual Land (R/W-Streets)
18	161	168	8	z	Acres of Land Sewered
19	169	176	8	z	Acres of Land Watered
20	177	184	8	z	# HH of Size 1
21	185	192	8	z	# HH of Size 2
22	193	200	8	z	# HH of Size 3
23	201	208	8	z	# HH of Size 4
24	209	216	8	z	# HH of Size 5
25	217	224	8	z	# HH of Size 6 and Over
26	225	232	8	z	# of White HH
27	233	240	8	z	# of Non-White HH
28	241	248	8	z	Population 5 years
29	249	256	8	z	Population 5 - 14 years

TABLE B - 2
(Continued)

EMPIRIC MODEL OUTPUT FILE FORMAT

Field #	Characters			Code	
	1st	Last	# of	PBZA	Field Description
30	257	264	8	z	Population 15 - 19 Years
31	265	272	8	z	Population 20 - 29 Years
32	273	280	8	z	Population 30 - 49 Years
33	281	288	8	z	Population 50 - 64 Years
34	289	296	8	z	Population 65 Years + Over
35	297	304	8	z	# Employees on Commercial Land
36	305	312	8	z	# Employees on Industrial Land
37	313	320	8	z	# Employees on Intensive Inst. Land
38	321	328	8	z	# Employees on Other Land
39	329	336	8	z	# of Single Family HH
40	337	344	8	z	# of Multi Family HH
41	345	352	8	z	# of HH With 0 Workers
42	353	360	8	z	# of HH With 1 Worker
43	361	368	8	z	# of HH With 2 + Workers
97	793	800	8	z	

APPENDIX C

ESTUARY HYDRODYNAMIC MODEL EQUATIONS AND CONSTANTS

$$R_o = \frac{A_o}{b}$$ [1a]

$$R_1 = \frac{A_1}{b}$$ [1b]

R_o = hydraulic radius of channel at start of time step (ft)

R_1 = hydraulic radius of channel at middle of time step (ft)

A_o = average cross section area of channel at start of time step (ft^2)

A_1 = average cross section area of channel at middle of time step (ft^2)

B = width of channel (ft)

$$K_o = \frac{g\,n^2}{2.208\,R_o^{4/3}}$$ [2a]

$$K_1 = \frac{g\,n^2}{2.208\,R_1^{4/3}}$$ [2b]

K_o = friction coefficient at start of time step

K_1 = friction coefficient at middle of time step

g = acceleration due to gravity (ft/sec^2)

n = Manning roughness coefficient

R_o = hydraulic radius at start of time step (ft)

R_1 = hydraulic radius at middle of time step (ft)

Subscript Notation:
o = beginning of time step
1 = middle of time step
2 = end of time step
o-1 = value during first half of time step
1-2 = value during second half of time step
o-2 = value during full time step

$$Y_o = (Y_o)_{nh} - (Y_o) \qquad [3a]$$

$$Y_1 = (Y_1)_{nh} - (Y_1)_{nl} \qquad [3b]$$

Y_o = change in head along channel between adjacent junctions at start of time step (ft)

Y_1 = change in head along channel between adjacent adjacent junctions at middle of time step (ft)

$(Y_o)_{nh}$ = head at next higher junction of channel at beginning of time step (ft)

$(Y_o)_{nl}$ = head at next lower junction of channel at beginning of time step (ft)

$(Y_1)_{nh}$ = head at next higher junction of channel at middle of time step (ft)

$(Y_1)_{nl}$ = head at next lower junction of channel at middle of time step (ft)

$$\Delta A_o = b \, \Delta Y_o \qquad [4a]$$

$$\Delta A_1 - b \, \Delta Y_1 \qquad [4b]$$

ΔA_o = change in cross section area of channel between adjacent junctions at start of time step (ft^2)

ΔA_1 = change in cross section area of channel between adjacent junctions at middle of time step (ft^2)

b = width of channel (ft)

ΔY_o = change in head along channel between adjacent junctions at start of time step (ft)

Y_1 = change in head along channel between adjacent junctions at middle of time step (ft)

$$q_1 = V_o A_o \tag{5a}$$

$$q_2 = V_1 A_1 \tag{5b}$$

q_1 = volumetric flow rate in channel leaving junction at midpoint of time step (ft^3/sec)

q_2 = volumetric flow rate in channel leaving junction at end of time step (ft^3/sec)

V_o = velocity in channel between adjacent junctions at beginning of time step (ft/sec)

V_1 = velocity in channel between adjacent junctions at middle of time step (ft/sec)

A_o = average cross section area of channel at start of time step (ft^2)

A_1 = average cross section area of channel at middle of time step (ft^2)

$$Q_1 = \Sigma q_1 + Q_R - Q_A \tag{6a}$$

$$Q_2 = \Sigma q_2 + Q_R - Q_A \tag{6b}$$

Q_1 = net volumetric flow rate from a junction at midpoint of time step (ft^{3}sec)

Q_2 = net volumetric flow rate from a junction at end of time step (ft^3/sec)

Σq_1 = algebraic sum of volumetric flow rates of all channels leaving a junction at middle of time step (ft^3/sec)

Σq_2 = algebraic sum of volumetric flow rates of all channels leaving a junction at end of time step (ft^{3}sec)

Q_R = volumetric rate of removal, at a junction, for water supply, irrigation, navigation, etc.during time step (ft^{3}sec)

Q_A = volumetric rate of addition, at a junction of liquid residuals, of streamflow, stormwater, etc. during time step (ft^3/sec)

$$Y_1 = Y_o - \frac{Q_1}{A_s} \Delta t_{o-2} \qquad [7a]$$

$$= Y_1 - \frac{Q_2}{A_s} \Delta t_{o-2} \qquad [7b]*$$

Y_1 = head at junction at middle of time step (ft)

Y_2 = head at junction at end of time step (ft)

Y_o = head at junction at start of time step (ft)

Q_1 = net volumetric flow rate from a junction at midpoint of time step (ft^3/sec)

Q_2 = net volumetric flow rate from a junction at end of time step (ft^3/sec)

A_s = surface area of junction equal to one-half the surface area of the preceeding and succeeding channels (ft^2)

Δt_{o-1} = duration of first half of time step (sec)

Δt_{o-2} = duration of whole time step (sec)

$$\Delta Y_{o-1} = 1/2 \left[(Y_1 - Y_o)_{nh} + (Y_1 - Y_o)_{nl} \right] \qquad [8a]$$

$$\Delta Y_{1-2} = 1/2 \left[(Y_2 - Y_1)_{nh} + (Y_2 - Y_1)_{nl} \right] \qquad [8b]$$

ΔY_{0-1} = average change in head along channel between adjacent junctions during first half of time step (ft)

ΔY_{1-2} = average change in head along channel between adjacent junctions during last half of time step (ft)

* except at boundary condition where the head of the most seaward junction varies with tide as calculated by Equation 12

$(Y_o)_{nh}$ = head at next higher junction of channel at start of time step (ft)

$(Y_o)_{nl}$ = head at next lower junction of channel at start of time step (ft)

$(Y_1)_{nh}$ = head at next higher junction of channel at middle of time step (ft)

$(Y_1)_{nl}$ = head at lower junction of channel at start of time step (ft)

$(Y_2)_{nh}$ = head at next higher junction of channel at end of time step (ft)

$(Y_2)_{nl}$ = head of next lower junction of channel at end of time step (ft)

$$A_1 = A_o + b \, \Delta Y_{o-1} \qquad [9a]$$

$$A_2 = A_1 + b \, \Delta Y_{1-2} \qquad [9b]$$

A_1 = average cross section area of channel at middle of time step (ft^2)

A_2 = average cross section area of channel at end of time step (ft^2)

A_o = average cross section area of channel at start of time step (ft^2)

b = width of channel (ft)

ΔY_{o-1} = average change in head along channel between adjacent junctions during first half of time step (ft)

ΔY_{1-2} = average change in head along channel between adjacent junctions during second half of time step (ft)

$$\frac{\Delta V}{\Delta X_{o-1}} = \frac{b \, \Delta Y_{o-1}}{A_o \Delta t_{o-1}} + \frac{V_o \Delta A_o}{A_o \quad x} \qquad [10a]$$

$$\frac{\Delta V}{\Delta X}_{1-2} = \frac{b\Delta Y_{1-2}}{A_1\Delta T_{1-2}} + \frac{V_1\Delta A_1}{A_1 \quad x} \qquad [10b]$$

$\frac{\Delta V}{\Delta X}_{o-1}$ = average velocity gradient along channel between adjacent junctions during first half of time step (ft/sec/ft)

$\frac{\Delta V}{\Delta X}_{1-2}$ = average velocity gradient along channel between adjacent functions during last half of time step (ft/sec/ft)

b = width of channel (ft)

x = length of channel (ft)

A_o = average cross section area of channel at start of time step (ft)

A_1 = average cross section area of channel at middle of time step (ft^2)

V_o = velocity in channel between adjacent junctions at start of time step (ft/sec)

V_1 = velocity in channel between adjacent junctions at middle of time step ft/sec)

ΔY_{o-1} = average change in head along channel between adjacent junctions during first half of time step

ΔY_{1-2} = average change in head along channel between adjacent junctions during last half of time step (ft)

Δt_{o-1} = duration of first half of time step (sec)

Δt_{1-2} = duration of last half of time step (sec)

$$V_1 = V_o + \left[-V_o \frac{\Delta V}{\Delta x}_{1-2} - K_o \left| V_o \right| - g \frac{\Delta Y_o}{x} \right] \Delta t_{o-1} \qquad [11a]$$

$$V_2 = V_1 + \left[-V_1 \frac{\Delta V}{\Delta x}_{1-2} - K_1 \left| V_1 \right| - g \frac{Y_1}{x} \right] \Delta t_{0-2} \qquad [11b]$$

V_1 = velocity in channel between adjacent junctions at middle of time step (ft/sec)

V_2 = velocity in channel between adjacent junctions at end of time step (ft/sec)

V_o = velocity in channel between adjacent junctions at start of time step (ft/sec)

$\left[\frac{\Delta V}{x} \right]_{o-1}$ = average velocity gradient along channel between adjacent junctions during first half of time step (ft/sec/ft)

$\left[\frac{\Delta V}{x} \right]_{1-2}$ = average velocity gradient along channel between adjacent junctions during last half of time step (ft/sec/ft)

K_o =friction coefficient at start of time step

K_1 =friction coefficient at middle of time step

g =acceleration due to gravity (ft/sec^2)

ΔY_o =change in head along channel between adjacent junctions at start of time step (ft)

ΔY_1 =change in head along channel between adjacent junctions at middle of time step (ft)

Δt_{o-1} =duration of first half of time step (sec)

Δt_{o-2} =duration of whole time step (sec)

x =channel length (ft)

APPENDIX D

Estuary Quality Model Equations

Parameter and Subscript Notation Used:

$(\quad)_o$ = beginning of quality time step

$(\quad)_1$ = end of quality time step

$(\quad)_a$ = mass transfer due to advection

$(\quad)_d$ = mass transfer due to diffusion

u = upstream junction of channel

d = downstream junction of channel

nh = next higher numbered junction

nl = next lower numbered junction

$(\;)_t$ = ambient water temperature

$(\;)_{20}$ = temperature at which reaction constants are evaluated

const = constituent

r = constituent (NH, BOD, DO, ChA, or NO_3)

A = liquid residuals (effluent flow) or streamflow additions to a junction

ChA = Chlorophyll A

$$(C_{const})_1 = \frac{(M_{const})_1}{V_1 \quad B_1} \qquad [1]$$

$(C_{const})_1$ = concentration of constituent in at end of time steps - (mg/l for NH_3, BOD, O_2, NO_3) and (ug/l for ChA)

$(M_{const})_1$ = mass of constituent in junction at end of time step (lb)

V_1 = volume of junction at end of time step (ft^3)

B_1 = conversion factor $\frac{1\ lb/ft^3}{16017\ mg/l}$ for NH_3, BOD, O_2, NO_3 and $\frac{1\ lb/ft^3}{16017000\ ug/l}$ for ChA

$$V_1 = V_0 + A_s \ (Y_1 - Y_0) \qquad [2]$$

V_1 = volume of junction at end of time step (ft^3)

V_0 = volume of junction at start of time step (ft^3)

A_s = surface area of junction equal to one-half the surface area of the preceeding and succeeding channels (ft^2)

Y_1 = head at junction at end of time step (ft)

Y_0 = head at junction of start of time step (ft)

$(M_{O_2})_1$ = $(M_{O_2})_0 + (\Delta M_{O_2})_a + (\Delta M_{O_2})_d + (\Delta M_{O_2})$
reaeration

$+ (\Delta M_{O_2})_{NH_3} + (\Delta M_{O_2})_{BOD} - (\Delta M_{O_2})$
respiration

$+ (\Delta M_{O_2})$ photosynthesis $- (\Delta M_{O_2})$ benthic

[3]

$(M_{O_2})_1$ = mass of oxygen as O_2 in junction at end of time step (lb)

$(M_{O_2})_0$ = mass of oxygen as O_2 in junction at start of time step (lb)

$(\Delta M_{O_2})_a$ = mass of oxygen as O_2 added to junction by advection from adjacent junctions during time step (lb)

$(\Delta M_{O_2})_d$ = Mass of oxygen as O_2 added to junction by diffusion from adjacent junctions during time step (lb)

$(\Delta M_{O_2})_{reaeration}$ = mass of oxygen as O_2 in junction added by reaeration during time step (lb)

$(\Delta M_{O_2})_{NH_3}$ = mass of oxygen as O_2 removed from junction by reaction with ammonia during time step (lb)

$(\Delta M_{O_2})_{BOD}$ = mass of oxygen removed from junction by reaction with carbonaceous material during time step (lb)

$(\Delta M_{O_2})_{respiration}$ = mass of oxygen as O_2 removed from junction by respiration throughout the full depth during time step (lb)

$(\Delta M_{O_2})_{photosynthesis}$ = mass of oxygen as O_2 added during photo synthesis by phytoplankton in the euphotic zone during 12 hour daylight portion of 24 hour light radiation cycle (lb)

$(\Delta M_{O_2})_{benthic}$ = mass of oxygen as O_2 removed from junction by reaction with the benthos of the junction during time step (lb)

$$(M_{const})_O = (M_{const})_1 + Q_A \; C_A \; t \; B_1 \qquad [4]$$

$(M_{const})_O$ = mass of constituent in junction at start of time step (lb)

$(M_{const})_1$ = mass of constituent in junction at end of previous time step (lb)

Q_A = volumetric rate of addition, at a junction of liquid residuals, of streamflow, etc. during time step (ft^3/sec)

t = duration of time step (sec)

C_A = concentration of constituent in liquid residuals, streamflow, etc. added to junction during time step (mg/l for NH_3, BOD, O_2, NO_3) and (ug/l for ChA)

B_1 = conversion factor $\frac{1 \text{ lb/ft}^3}{16017 \text{ mg/l}}$ for NH_3, BOD, O_2, NO_3

and $\frac{1 \text{ lb/ft}^3}{16017000 \text{ ug/l}}$ for ChA

$$\Delta M_a = q_1 \; C^* \; \Delta t \; B_1 \qquad [5]$$

ΔM_a = mass advected from upstream junction to downstream junction during time step (lb)

C^* = constituent concentration of the advected mass (mg/l for NH_3, BOD, O_2, NO_3) (ug/l for cholorphyl A)

Δt = duration of time step (sec)

q_1 = volumetric flowrate in channel leaving junction at end of time step (ft^3/sec)

B_1 = conversion factor $\frac{1 \text{ lb/ft}^3}{16017 \text{ mg/l}}$ for NH_3, BOD, O_2, NO_3

$\frac{1 \text{ lb/ft}^3}{16017000 \text{ ug/l}}$ for ChA

$$C^* = C_u - 0.25 \quad (C_u - C_d) \qquad [6]$$

C^* = constituent concentration of the advected mass (mg/l, ug/l for ChA)

C_u = upstream constituent-concentration at adjacent junction (mg/l, ug/l for ChA)

C_d = downstream constituent-concentration at adjacent junction (mg/l, ug/l for ChA)

$$\Delta M_d = K_d \quad A \quad \frac{\Delta C}{X} \qquad t B_2 \qquad [7]$$

ΔM_d = mass of constituent transferred by diffusion from the junction of higher concentration through a channel to the junction of lower concentration during the time step (lb)

K_d = diffusion coefficient in the channel during the time step (ft^2/sec)

$\frac{\Delta C}{X}$ = concentration gradient of the channel between adjacent junctions (mg/l/ft, mg/l/ft for ChA)

X = length of channel (ft)

Δt = duration of time step

A = cross section area of channel (ft^2)

B_2 = conversion factor $\frac{1 \text{ lb}}{453.5 \text{mg}}$

$$K_d = C_4 \quad V \quad R_O \qquad [8]$$

K_d = diffusion coefficient in the channel during the time step (ft^2/sec)

C_4 = constant (equal to 0.2)

V = velocity of flow in channel (ft/sec)

R_O = hydraulic radius of channel (ft)

$$R_1 = R_O + 1/2 \left[(Y_1 - Y_O)_{NH} + (Y_1 - Y_O)_{NL} \right] \qquad [9]$$

R_1 = hydraulic radius of channel between adjacent junctions at end of time step (ft)

R_O = hydraulic radius of channel between adjacent junctions at start of time step (ft)

$(Y_1)_{nh}$ = head at next higher junction of channel at end of time step (ft)

$(Y_O)_{nh}$ = head at next higher junction of channel at start of time step (ft)

$(Y_1)_{nl}$ = head at next lower junction of channel at end of time step (ft)

$(Y_O)_{nl}$ = head at next lower junction of channel at start of time step (ft)

$$(\Delta M_{O_2})_{reaeration} = K_{r_2} \; D \; V_O \; B_1 \qquad [10]$$

$(\Delta M_{O_2})_{reaeration}$ = mass of oxygen in junction added by reaeration during time step (lb)

K_{r_2} = ratio of mass of oxygen in junction added by reaeration to the mass of oxygen deficit at start of time step

D = dissolved oxygen saturation deficit occurring during time step (mg/l)

V_O = volume of junction at start of time step (ft^3)

B_1 = conversion factor $\frac{1 \text{ lb/ft}^3}{16017 \text{ mg/l}}$

$$K_{r_2} = 1-(e)^{-(K_2)_t \Delta t} \qquad [11]$$

K_{r_2} = ratio of mass of oxygen added by reaeration during time step to the mass of oxygen deficit at start of time step.

$(K_2)_t$ = reaeration coefficient (day^{-1},)

e = 2.718, base of Naperian log system

Δt = duration of time step (sec)

r = O_2

$$(K_2)_t = (C)_t V^a Y_{0_b} \qquad [12]$$

$(K_2)_t$ = reaeration coefficient (day^{-1})

V = velocity in channel (ft/sec)

Y_0 = depth (ft)

a = proportionality constant between $\log_n K_2$ and $\log_n V$

b = proportionality constant between $\log_n K_2$ and $\log_n Y_0$

$(C)_t$ = constant in reoxygenation equation which varies with temperature

$$(C)_t = (C)_{20} \ (\theta)^{t-20} \qquad [13]$$

$(C)_t$ = constant in reoxygenation equation at water temperature simulated

$(C)_{20}$ = constant in reoxygenation equation at 20° centigrade

t = water temperature simulated ($^{\circ}C$)

θ = constant reflecting the effect of temperature on the reoxygenation equation

$$(\Delta M_{O_2})_{NH_3} = 4.57 \quad (\Delta M_{NH_3})_b \qquad [14]$$

$(\Delta M_{O_2})_{NH_3}$ = mass of oxygen as O_2 removed from junction by reaction with ammonia as N during time step (lb)

4.57 = ratio of ultimate nitrogenous oxygen demand as O_2 to ammonia as N *

$(\Delta M_{NH_3})_b$ = mass of ammonia as N removed from junction by reaction with dissolved oxygen as O_2 during time step (lb)

$$(\Delta M_{O_2})\ \text{respiration} = V_O \ K_{resp} \ B_1 \ (C_{ChA})_O \ \Delta t \qquad [15]$$

$(\Delta M_{O_2})_{respiration}$ = mass of oxygen as O_2 removed from junction by respiration throughout the full depth of the junction during time step (lb)

V_O = volume of junction at start of time step (ft^3)

K_{resp} = rate of oxygen consumption during respiration of phytoplankton capable of photosynthesis (mg O_2/hr/ug ChA)

$(C_{ChA})_O$ = concentration of chlorophyll A in junction at start of time step (ug/l)

Δt = duration of time step (hr)

B_1 = conversion factor $\frac{1\ \text{lb}}{453.6\ \text{mg}}$

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* $NH_3 + 3/2\ O_2 \rightleftharpoons HNO_2 + H_2O$

$NO_2 + 1/2\ O_2 \rightleftharpoons NO_3$

$$\frac{(3/2 \ + \ 1/2) \quad (\text{Mol.wt.}O_2 \text{ as } O_2)}{(\quad 1 \quad) \quad (\text{Mol.wt.}NH_3 \text{as N})} = \frac{64}{14} = 4.57$$

(ΔM_{O_2}) photosynthesis = $V_p \; K_{photo} \; B_1 \; (C_{ChA})_o \; \Delta t$ [16]

(ΔM_{O_2}) photosynthesis = mass of oxygen as O_2 added to junction by photosynthesis in the euphotic zone during 12 hour daylight portion of 24 hour light radiation cycle (lb)

V_p = volume of euphotic zone at start of time step (ft^3)

K_{photo} = rate of oxygen production during photosynthesis by phytoplankton in the euphotic zone during time step (mg O_2/hr/ug ChA)

$(C_{ChA})_o$ = concentration of chlorophyll A in junction at start of time step (ug/l)

B_1 = conversion factor $\frac{1 \text{ lb}}{453.6 \text{mg}}$

Δt = duration of time step (hr)

$V_p = A_s \; E_p$ if $V_o \geq V_p$ [17a]

$V_p = V_o$ if $V_o < V_p$ [17b]

V_p = volume of euphotic zone of junction at start of time step (ft^3)

V_o = volume of junction at start of time step (ft^3)

A_s = surface area of junction (ft^2)

E_p = depth of euphotic zone (ft)

$(\Delta M_{O_2})_{benthic} = A_s \; K_{benth} \; \Delta t \; B_2$ [18]

(ΔM_{O_2}) benthic = mass of oxygen as O_2 removed from junction by reaction with the benthos of the junction during time step (lb)

A_s = surface are of the junction (ft^2)

K_{benth} = rate of oxygen consumption by benthos (g/m^2 day)

Δt = duration of time step (day)

B_2 = conversion factor

$$(M_{NH_3})_1 = (M_{NH_3})_0 + (\Delta M_{NH_3})_a + (\Delta M_{MH_3})_d - (\Delta M_{NH_3})_b \quad [19]$$

$(M_{NH_3})_1$ = mass of ammonia as N in junction at end of time step (lb)

$(M_{NH_3})_0$ = mass of ammonia as N in junction at start of time step (lb)

$(\Delta M_{NH_3})_a$ = mass of ammonia as N added to junction by diffusion from adjacent junctions during time step (lb)

$(\Delta M_{NH_3})_b$ = mass of ammonia as N removed from junction by reaction with oxygen during time step (lb)

$$(\Delta M_{NH_3})_b = (1-K_{r_1}) \; C_0 \; V_0 \; B_1 \quad [20]$$

$(\Delta M_{NH_3})_b$ = mass of ammonia as N removed from junction by reaction with oxygen to form nitrate during time step (lb)

K_{r_1} = ratio of mass of ammonia in junction at end of time step to mass of ammonia in junction at start of time step due only to decay

C_0 = concentration of ammonia as N in junction at start of time step (mg/l)

V_0 = volume of junction at start of time step (ft^3)

B_1 = conversion factor $\frac{1 \ lb/ft^3}{16017 \ mg/l}$

r = NH_3

$$K_{r_1} = e^{-(K_1)_t \Delta t} \qquad [21]$$

K_{r_1} = ratio of mass of constituent in junction at end of time step to mass constituent at start of time step at water temperature t

K_1 = reaction rate of constituent to form a different constituent at water temperature t (day $^{-1}$, base e)

e = 2.718, base of Naperian log system

Δt = duration of time step

r = NH_3, BOD, ChA, or NO_3

$$(K_1)_t = (K_1)_{20} \ \theta \ (t-20) \qquad [22]$$

$(K_1)_t$ = reaction rate of a constituent to form a different constituent at water temperature t; also called the decay rate (day^{-1}, base e)

$(K_1)_{20}$ = decay rate of a constituent at 20° centigrade (day^{-1}, base e)

θ = constant reflecting the effect of temperature on the reaction rate of a constitutent

t = water temperature simulated (°C)

$$(M_{BOD}O_1 = (M_{BOD}O)_O + (\Delta M_{BOD})_a + (\Delta M_{BOD})_d - (\Delta M_{BOD})_b \qquad [23]$$

$(M_{BOD})_1$ = mass of BOD_5 as O_2 in junction at end of time step (lb)

$(M_{BOD})_O$ = mass of BOD_5 as O_2 in junction at start of time step (lb)

$(\Delta M_{BOD})_a$ = mass of BOD_5 as O_2 added to junction by advection from adjacent junctions during time step (lb)

$(\Delta M_{BOD})_d$ = mass of BOD_5 as O_2 added to junction by diffusion from adjacent junctions during time step (lb)

$(\Delta M_{BOD})_b$ = mass of BOD_5 as O_2 removed from junction by reaction with dissolved oxygen during time step (lb)

$$(\Delta M_{O_2})_{BOD} = BOFD\ (\Delta M_{BOD})_b\ R_3 \qquad [24]$$

$(\Delta M_{O_2})_{BOD}$ = mass of oxygen as O_2 removed from junction by reaction of dissolved oxygen with biochemical oxygen demanding substances during time step (lb)

BOFD = ratio of ultimate oxygen demand to five day biochemical oxygen demand

$(\Delta M_{BOD})_b$ = mass of BOD_5 as O_2 removed from junction by reaction with dissolved oxygen as O_2 during time step (lb)

R_3 = ratio of oxygen as O_2 to ultimate BOD $\frac{1\ mg\ O_2}{1\ mg\ BOD_{ult}}$

$(\Delta M_{BOD})_b = (1 - K_{r_1})\ C_O\ V_O\ B_1$

$(\Delta M_{BOD})_b$ = mass of five day BOD as O_2 removed from junction by reaction with oxygen during time step (lb) [25]

$1 - K_{r_1}$ = ratio of biochemcial oxygen demand exerted during time step to ultimate oxygen demand at start of time step

C_O = concentration of BOD_5 as O_2 in junction at start of time step (mg/l)

V_O = volume of junction at start of time step (ft^3)

B_1 = conversion factor $\frac{1\ lb/ft^3}{16017 mg/l}$

BODF = e (K_1) t(5 days) [26]

BODF = ratio of ultimate oxygen demand to five day biochemical oxygen demand

$(K_1)_t$ = reaction rate of oxygen demanding substances with dissolved oxygen, at water temperature t; also called the decay rate (day^{-1}, base e)

$$(MChA)_1 = (MChA)_O + (\Delta MChA)_a + (\Delta MChA)_2 - (\Delta MChA + (\Delta M_{NO_3})b \left[\frac{R_1}{B_2}\right] \qquad [27]$$

$(MChA)_1$ = mass of chlorophyll A in junction at end of time step (lb)

$(MChA)_O$ = mass of chlorophyll A in junction at start of time step (lb)

$(\Delta MChA)_a$ = mass of chlorophyll A added to junction by advection from adjacent junctions during time step (lb)

$(\Delta MChA)_d$ = mass of chlorophyll A added to junction by diffusion from adjacent junctions during time step (lb)

$(\Delta MChA)_b$ = mass of chlorophyll A removed from junction by predators, etc. during time step (lb)

$(\Delta M_{NO_3})_b$ = mass of nitrate as N removed from junction by incorporation into photosynthetic phytoplankton during time step (lb)

R_1 = ratio of chlorophyll A to nitrate as N in phtosynthetic phytoplankton $\frac{93 mgChA}{1 mg\ atom\ NO_3}$

B_2 = conversion factor $\frac{1\ lb}{453.6\ mg}$

$$(\Delta MChA)_b = (1 - K_{r_1})C_O V_O B_1 \qquad [28]$$

$(\Delta MChA)_b$ = mass of chlorophyll A removed from junction by predators, etc. during time step (lb)

K_{r_1} = ratio of mass of chlorophyll A in junction at end of time step to mass of chlorophyll A in junction at start of time step due only to decay (lb)

C_O = concentration of chlorophyll A in junction start of time step (mg/l)

V_O = volume of junction at start of time step (ft^3)

B_1 = conversion factor $\frac{1\ lb/ft^3}{16017000 ug/l}$

$$(M_{NO_3})_1 = (M_{NO_3}) + (\Delta M_{NO_3})_a + (\Delta M_{NO_3})_d - (\Delta M_{NO_3})_b + (\Delta M_{NH_3})_b \; R_2 \qquad [29]$$

$(M_{NO_3})_1$ = mass of nitrate as N in junction at end of time step (lb)

$(M_{NO_3})_O$ = mass of nitrate as N in junction at start of time step (lb)

$(\Delta M_{NO_3})_a$ = mass of nitrate as N added to junction by advection from adjacent junction during time step (lb)

$(\Delta M_{NO_3})_d$ = mass of nitrate as N added to junction by diffusion from adjacent junctions during time step (lb)

$(\Delta M_{NO_3})b$ = mass of nitrate as N removed from junction by incorporation into phtosynthetic phytoplankton during time step (lb)

$(\Delta M_{NH_3})b$ = mass of ammonia as N removed from junction by reaction with oxygen to form nitrate during time step (lb)

R_2 = ratio of ammonia as N to nitrate as N $\dfrac{1 \text{ mgNO}_3 \text{ as N}}{1 \text{ mgNH}_3 \text{ as N}}$

$$(\Delta M_{NO_3})_b = (1 - K_{r_1}) \quad C_O V_O B_1 \qquad [30]$$

$(\Delta M_{NO_3})_b$ = mass of nitrate as N removed from junction by incorporation into photosynthetic phytoplankton during time step (lb)

K_{r_1} = ratio of mass of nitrate as N in junction at end of time step to mass of nitrate in junction at start of time step due only to decay

C_O = concentration of nitrate in junction at start of time step (mg/l)

V_O = volume of junction at start of time step (ft^3)

B_1 = conversion factor $\dfrac{1 \text{ lb/ft}^3}{16017 \text{ mg/l}}$

CONSTANTS

TIME STEP

$\Delta t = 30$ min

DIFFUSION

$C_y = 1.0$

REAERATION (using O'Connor Dobbins Equation)

$(C)_{20} = 12.9$

$a = 1/2$

$b = -3/2$

$\theta = 1.021$

RESPIRATION

$0.0006 \leq K_{resp} \leq 0.0008$ mg O_2/hr/ug ChA

PHOTOSYNTHESIS

$K_{photo} = 0.012$ mg O_2/hr/ug ChA by day

K photo = 0 by night

BENTHIC DEMAND

$K_{benth} = 1.0$ gram O_2/m^2/day

REACTION RATES (first order)

CONSTITUENT	DECAY PROCESS	DECAY CONSTANT $(K_1)_t$ in day^{-1}, base t=20 °C	t=27 °C
NH_3	oxidation	0.23	0.23
BOD_5	oxidation	0.17	0.23
ChA	predation	0.04	0.04
NO_3	uptake	0.09	0.09

CONVERSION CONSTANTS

$$R_1 = \frac{93 \text{ ug ChA}}{1 \text{ mg } NO_3 \text{ as N}}$$

$$R_2 = \frac{1 \text{ mg } NO_3 \text{ as N}}{1 \text{ mg } NH_3 \text{ as N}}$$

$$R_3 = \frac{1 \text{ mg } O_2}{1 \text{ mg BOD ult as } O_2}$$

O_2 SATURATION VS. TEMPERATURE

$$C_{SAT} = 14.652 - 0.41022T + 0.0079910T^2 - 0.00077779T^3$$

LIQUID RESIDUAL CONCENTRATIONS

C_{O_2} = 2.0 mg/1

C_{NH_3} = 12.0 mg/1

STORMWATER RUNOFF CONCENTRATIONS

C_{O_2} = SATURATION

C_{NH_3} = 0

WATER TEMPERATURE

t = 27C